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Cover: One of the best-known icons of the work of the Canadian Wildlife Service to ensure the survival of endangered species is the Whooping Crane, *Grus americana*. This one, incubating on its nest in a remote corner of Wood Buffalo National Park, was photographed by Dalton Muir in 1974.

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A Passion for Wildlife: A History of the Canadian Wildlife Service, 1947–1997

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The Dominion Wildlife Service was created by Order-in-Council in November 1947 with fewer than 30 staff gathered from diverse federal agencies. In 1950, the name was changed to the Canadian Wildlife Service, and under that name the agency has become internationally recognized. Although its mandate most clearly focused on the management of migratory birds, as defined under the Migratory Birds Convention Act, on game and furbearing mammals, and on the enforcement of international treaties for the conservation of species, in carrying out these responsibilities it has originated research on critical species and the factors affecting their survival throughout the country. Over 50 years, this has involved, among other studies, primary ones on Elk, Moose, and Bison in National Parks, the dynamics of northern species such as Caribou, Muskoxen, Polar Bears, Wolves, and Arctic Foxes, the population ecology and migration patterns of geese and ducks, songbird surveys, shorebird and seabird studies, major initiatives in the conservation of the Trumpeter Swan, Whooping Crane, and Peregrine Falcon, and limnological studies of the health of lakes to enhance fish production. As well as conducting research in National Parks for several decades, the Service has managed federal sanctuaries and wildlife areas including such well-known ones as Last Mountain Lake and those on the north shore and gulf of the St. Lawrence River. It has been a leader in research on environmental toxicology and effects of toxic substances on wildlife, contributed to the Canada Land Inventory Program, and developed innovative public education programs such as interpretive nature centres and the "Hinterland Who's Who" series in print and on television. It has also enforced federal wildlife regulations, initiated habitat conservation programs, and promoted both federal–provincial and international cooperation in wildlife conservation. A major role has been coordinating endangered species evaluation and protection, both within Canada on COSEWIC (Committee on the Status of Endangered Wildlife in Canada) and internationally through CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). It is a leader in proposed legislation expected to result in an endangered species act for Canada. Throughout its history its legends and accomplishments have bound the Wildlife Service into a unit whose employees' pride and passion have enabled it to survive resource reductions, decentralizing, and reorganizations and to remain innovative, vigorous, and relevant for the conservation and enforcement challenges yet to come. Its story is enhanced here by the reminiscences of many Wildlife Service veterans.

Key Words: Canadian Wildlife Service, migratory birds, waterfowl, furbearers, endangered species, sanctuaries, wildlife areas, toxicology, shorebirds, seabirds, CITES, COSEWIC.

Preface

When I was a young boy in the early 1950s, I had the good fortune to be a member of the Toronto Junior Field-Naturalists' Club. Once a month, on a Saturday morning, I would travel by bus and streetcar to the Royal Ontario Museum where, from 10 till noon, my eyes and mind and imagination were filled to overflowing with information about the fauna and flora that populated the city's ravines where my friends and I played and the more distant wetlands and woodlands where we went on club field trips.

I grew up immersed in the belief that a most precious part of my birthright as a Canadian was the opportunity to experience the natural world around me with respect and delight. I was, furthermore, convinced that my country shared that belief. Had it not established remarkable agencies to study our natural heritage and to inform the world about it? Those

A version in French of this history will appear in 1999 as Volume 123, Number 2 of *Le Naturaliste canadien*, published by La Société Provancher d'histoire naturelle du Canada, 9141 avenue du Zoo, Charlesbourg, Quebec G1G 4G4, Canada.

agencies were the National Film Board of Canada, which produced so many of the nature documentaries that we watched in that darkened museum theatre on Saturday mornings, and the Canadian Wildlife Service (CWS), whose biologists and technicians became our mentors as we watched them on the screen.

Some kids dreamed of becoming firefighters, jet pilots, nurses, engineers. I dreamed of being a filmmaker or a wildlife biologist. As it happened, I didn't become either, but, indirectly, my dreams came true. I worked for 15 years with the National Film Board, although never as a filmmaker; and for the past 12 years I have had the enormous satisfaction of collaborating with the Wildlife Service, in the guise of a writer, on projects that have taken me from Witless Bay and Cape St. Mary's to Vancouver Island, with many fascinating stops in between. Those experiences have confirmed my initial sense that CWS is one of Canada's most important and valuable cultural institutions.

I use the term cultural advisedly, not in the narrow sense that pertains only to music, literature, theatre, and the visual arts, but with reference to the whole rich fabric of behaviours and values that bind Canadians of so many diverse origins into a recognizable society. In that broad sense, I would suggest that the widespread valorization of wilderness and wildlife is one of our national traits. In that broad sense, CWS has helped us to discover and acknowledge what an important dimension our relationship with the natural world adds to our culture and identity as Canadians.

I felt enormously privileged, therefore, in the fall of 1996, to be invited by Environment Canada to write a 50th anniversary history of the Wildlife Service. Since then, I have met and interviewed more than 120 of the agency's employees, past and present. Not one of them expressed regret at his or her career choice, nor left any doubt that a life devoted to the study and protection of wildlife was a life well spent. How many other organizations can boast such unanimity of purpose? Driven by a passionate interest in the natural world and a deep commitment to protect it from abuse, members of the CWS family have gone out into this thinly populated land, often at considerable personal risk, and have come back to tell us the wonder of what is ours and why it matters. In a country that tends to deprecate heroism, the personnel of the Wildlife Service are numbered among our unsung Canadian heroes.

The challenge of telling their story has been, by turns, humbling, frustrating, and deeply rewarding. History is, at best, an imperfect interpretation of incomplete data. The present example is no exception. Drawn variously from oral and written accounts, it incorporates the strengths and limitations of both kinds of source material. Many who contributed time and recollections expressed the hope that the finished work would be heavily anecdotal, focusing on the characters and exploits that make up the legendary CWS. Others urged that it provide an accurate, factual outline of the evolution of Canadian administrative policies, programs, personnel, and practices on behalf of wildlife over half a century. Still others felt the history should serve as a concordance to the scientific accomplishments and publications of the organization. None will be wholly satisfied. All, I hope, will recognize a sincere effort to achieve a reasonable balance among these competing objectives.

A word or two about the structure of the book is probably in order. Throughout its history, CWS has operated on so many fronts at once that to recount its accomplishments in chronological order would have been needlessly complex and confusing. Instead, I have chosen a thematic approach. The first chapter sets the context in which CWS was established in 1947 by providing a brief overview of wildlife policy in Canada up to the 1940s. In writing it, I drew heavily on Janet Foster's excellent book, *Working for Wildlife,*[1] which is, I believe, the only comprehensive account that has been written on this important aspect of Canadian history. The remaining chapters deal with major areas to which CWS has devoted its talents and resources over the years. These include enforcement, ornithology, mammalogy, limnology, habitat protection, interpretation, toxicology, endangered species protection, and governance. Interspersed between these thematic chapters are shorter sections, each providing a chronological summary of key events in the organizational development of CWS during a specific five-year period.

After nearly two years of research, contemplation, composition, and revision, I am deeply conscious of how many people, projects, and events have received but cursory attention or none at all in this telling of their history. To those who regret the absence of a particular tale, or train of events, or singular achievement, or memorable personality, I can only say that I acknowledge the absence and I share your regret. The inclusion of some individuals and topics and the omission of others does not imply a hierarchy of significance. The simple fact is that within the constraints of time and space, a relative handful of figures and themes had to be chosen to represent the whole. Like an iceberg, 90% of the Wildlife Service story remains hidden beneath the surface, waiting for the day when a different 10% will be revealed. I hope those who recognize the gaps in this attempt will not hesitate to fill them with histories of their own.

Having offered that caveat, I also wish to acknowledge the contribution of so many members of the CWS family for their assistance and encouragement. Without exception, those to whom I have turned for information and advice have given unstintingly of their time and knowledge. To all, I express my sincere appreciation. To some, I must extend particular thanks.

First, to Pat Logan and Tony Keith, advisors and project coordinators extraordinaire, I owe an immense debt for help, guidance, patience, editorial expertise, and unfailing confidence that this project would come to fruition.

In addition, two CWS veterans, Vic Solman and Joe Bryant, have been on hand to nurture the undertaking, almost from the outset. Vic's enthusiastic feedback invariably provided a tonic to my flagging spirits. Joe's incisive editorial notes, as courteous as they were copious and uncompromising, reminded me of the high standard of scholarly excellence to which CWS has aspired over the years and motivated me to try my best to match it. If anyone deserves a credit as coauthor of this history, it is he.

Special mention should be made, too, of Jim Foley, who foresaw the need for a history of CWS several years ago, who developed repeated proposals for its production, and who had the foresight to begin gathering his own archive of significant publications and documents.

During the research phase of the project, I enjoyed hearing the reminiscences of dozens of informative CWS sources. Starting on the west coast, I must mention the gracious gift of time afforded by Yorke Edwards, Ron Mackay, Art Martell, Rick McKelvey, and David Munro.

In Edmonton, Gerry Beyersbergen organized a whirlwind schedule of interviews with Lu Carbyn, Richard Fyfe, Gordon Kerr, Ernie Kuyt, Andrew Macpherson, Gerry McKeating, Frank Miller, Hal Reynolds, Len Shandruk, Jack Shaver, Ed Telfer, Garry Trottier, and himself, and then had the good sense to arrange an unforgettable winter morning of recuperation from information overload, among the Bison at Elk Island National Park.

In Ottawa, in addition to those noted above, I was greatly helped by Hugh Boyd, David Brackett, Eric Broughton, Barbara Campbell, Joe Carreiro, Chuck Dauphiné, Debbie Harris, Alan Loughrey, Pierre Mineau, Guy Morrison, Ross Norstrom, Nick Novakowski, John Tener, Gaston Tessier, and Steve Wendt, as well as Graham Cooch and Jim Patterson, whom I had the great pleasure of meeting at the anniversary celebration on 1 November 1997.

My guide to the Quebec Region was Gilles Chapdelaine, who put me in touch with Luc Bélanger, André Bourget, Marcel Laperle, Denis Lehoux, Austin Reed, Isabelle Ringuet, Jean Rodrigue, Jean-Pierre Savard, and Jacqueline Vincent.

In the Atlantic Region, special thanks must go to Al Smith and George Finney, with whom my CWS association was initiated in 1986, to Tony Erskine, who never failed to provide helpful guidance in tracking down a detail or a source, and to Jean Sealy, who was endlessly helpful in finding references and arranging interlibrary loans. Invaluable assistance was also gratefully received from Dick Brown, Neil Burgess, Dan Busby, Richard Elliot, Ross Galbraith, Peter Hicklin, Joe Kerekes, Tony Lock, David Nettleship, Gerry Parker, Dave Paul, Peter Pearce, Jim Stoner, and Wayne Turpin.

When the time came to review the manuscript in its various draft stages, many of the above-named individuals, and a wide selection of others, volunteered useful corrections, amendments, and additions — especially additions! In half a century, CWS has accrued enough facts and enough fiction to fill this modest volume many times over. Thank you for all your suggestions, and for your forbearance at my inability to incorporate more than a few of them.

Among those not already named who provided extensive input at the review stage, I must mention Rob Butler, Jean Cinq-Mars, Jean-Paul Cuerrier, Kathy Dickson, Jean Gauthier, Gerry Lee, David Peakall, Don Russell, George Scotter, and Ian Stirling. In addition, I particularly wish to thank Marla Sheffer for a thorough, thoughtful, and highly professional job of copy editing and for preparing the index.

I also want to express my appreciation to the authors of two special letters, parts of which appear in the epilogue to this history. They are Janet Foster, preeminent chronicler of the history of wildlife conservation in Canada up to the 1920s, and Monte Hummel, long-time leader of World Wildlife Fund Canada and nongovernment partner and collaborator with CWS in many conservation initiatives.

Credit is due, as well, to those who delved into their personal photographic collections to provide many of the images that illustrate the text. And without the faith and financial support of the Executive Committee of CWS, this project would not have been possible.

To all these, and to the many, many others who added directly or indirectly to the richness and the vitality of this account of CWS, my heartfelt thanks. Together, we've made a good start. I truly hope that others will not hesitate, now, to produce their own memoirs and interpretations, retelling the CWS story in other ways, until a composite view emerges that can do justice to the whole.

J. ALEXANDER (SANDY) BURNETT
Sackville, New Brunswick
September 1998

Notes

1. Janet Foster, *Working for Wildlife: The Beginning of Preservation in Canada* (Toronto: University of Toronto Press, 1978).

CHAPTER 1. Exercising Dominion: The Genesis of Canadian Wildlife Policy

Discovery and Disillusionment

Many and varied though the early explorers were who "discovered," mapped, and catalogued the resources of Canada, most shared certain experiences. A frequently recurring theme in the written records of their explorations is their wonder at the abundance of wildlife. Norse rovers, familiar as they were with the teeming eider colonies of Iceland, were amazed to find eider nests on the rocky offshore islands of the New World so close together that it was hard to walk among them without breaking eggs.[1] Nearly 700 years later, in 1672, Nicolas Denys, discussing the Seal Islands off present-day Yarmouth, Nova Scotia, remarked that:

> Upon these [islands] is so great a number of all kinds of birds that it is past belief, and especially during the spring when they build their nests. If one goes there he makes them rise in such vast numbers that they form a cloud in the air which the sun cannot pierce; and to kill them it is not necessary to use guns, but simply clubs, for they are sluggish in rising from their nests. As to the young ones, they can be taken as many as wished even to loading the boats, and the same with the eggs.[2]

Dozens of other observers sent back comparable accounts. So it is with discovery. In order to finance further exploration, explorers become publicists of the new lands they have found. If a place shows the least promise of being hospitable and profitable, then the tales quickly accumulate, of rivers that flow with milk and honey and birds and beasts beyond number that greet the traveller with innocent eyes. Abundance beyond belief, beyond the possibility of exhaustion, is the message carried back to fire the imagination and desire of those who stayed at home, so that next time they too will make the voyage, conquer the wilderness, and claim their share.

Once generated, the myth of limitless bounty can be hard to eradicate. This was especially true in Canada, a land where fur, fish, and game were, for centuries, the principal attractions to settlement. How vast the flocks of birds, the schools of fish, and the herds of Bison really were in their prime may never be known. By the time anyone set out to count them, their original numbers were already the stuff of campfire tales. As settlement followed exploration, the vulnerability of even the most abundant wildlife became apparent. As early as 1785, an observer had written of Funk Island:

> It has been customary...for several crews of men to live all summer on the island for the purpose of killing [Great Auks] for the sake of their feathers....If a stop is not put to that practice, the whole breed will be diminished to almost nothing.[3]

The prophecy was not slow to be fulfilled. By 1800, the great flightless birds were gone from Funk Island, and by 1844, the species was extinct. Nor was the Great Auk the only creature to suffer. John James Audubon, visiting the Gulf of St. Lawrence in 1833, deplored the wholesale egging that he witnessed at seabird colonies on the islands along the north shore and the unbridled clubbing to death of gannets on Bird Rocks.[4] At that time, the site, with a population of more than 100 000 breeding pairs, was the largest Northern Gannet colony in the world.[5] By 1916, only about 450 pairs remained.[6]

To the west, John Palliser had noted "immense buffalo herds" in 1857, but three years later, in 1860, he remarked that "on the southern prairie they are becoming very scarce" and speculated that the introduction of firearms to the hunt might be a contributing factor.[7] By 1890, the last of the great wild buffalo herds were gone. So, too, were most of the Passenger Pigeons, whose crop-destroying hordes had been the object of an exorcism by Monseigneur de Laval, Bishop of Quebec, in 1686.[8] All but a scattered remnant of another favourite target of market hunters and sportsmen, the "doughbird" or Eskimo Curlew, were gone. The last Labrador Duck in Canada was seen on Grand Manan in 1874; the last Sea Mink was killed on Campobello Island in 1894; and in British Columbia, the Sea Otter was fast approaching extirpation.

Changing Perceptions

> With the advance of settlement, animal life retreats. The western plains, so lately thronged with herds of elk and antelope and roamed over by countless herds of bison, are yearly required more and more for human pasture, instead of nature's feeding ground. Hills, valleys, forests, and meadows everywhere are alike coming under man's control, thereby rapidly pushing to the verge of extinction many species of animals which were formerly abundant.[9]

Even as wildlife populations plummeted before the advance of Victorian civilization, a few people in government were attempting to stem the tide of reckless consumption. As early as 1762, Sir Thomas Gage, military governor of Canada, had declared a closed season on partridge (Ruffed Grouse), although whether his objective was to conserve wildlife or simply to ensure that there would be good shooting for officers and gentlemen is unclear. The first comprehensive game law in Upper Canada was passed in 1839, setting limits and seasons for several species. In 1856, protection was extended to fur-bearing mammals, and in 1864, to beneficial (i.e., insectivorous) nongame birds.[10]

Even as early protective measures such as these were being introduced, the systematic study of Canadian flora and fauna was emerging as a legiti-

CWS field parties have often traced the footsteps of earlier explorers. At Winter Harbour, Melville Island, in 1961, Don Thomas examines the rock marking the westward limit of William Parry's search for the Northwest Passage (1819–1820) and bearing a plaque on which Joseph-E. Bernier claimed the Arctic Archipelago for Canada in 1909 (Photo credit: D. Thomas).

mate field of scientific investigation. Interested individuals included Samuel de Champlain and Nicolas Denys in the 17th century, and Peter Kalm, the assistant of Linnaeus, in the 18th. As time passed, increasing numbers of exploration and survey parties considered the gathering of data on the natural history of the regions through which they travelled to be a part of their task. Naturalist William Anderson had sailed with James Cook, collecting birds in 1778, and Royal Navy surgeon Archibald Menzies doubled as ship's botanist under George Vancouver in 1792–1793. The Palliser Expedition (1857–1860) included among its members a geologist and naturalist, Dr. John Hector, and a botanical collector, Eugène Bourgeau. Henry Youle Hind served as geologist/naturalist with expeditions to the Red, Assiniboine, and South Saskatchewan rivers in 1857–1858. In 1872, when Sandford Fleming was organizing the first of a series of government surveys aimed at selecting a route for the Canadian Pacific Railway, he invited John Macoun[11] to join the expedition as botanist.[12]

Macoun's participation in frequent western explorations over the next decade provided him with a wealth of field experience and a growing reputation as a botanical geographer. In addition, it brought him to the attention of A. R. C. Selwyn, Director of the Geological Survey of Canada, whom he accompanied on his landmark trek of 1875, which pushed eastward through the interior of British Columbia and down the Peace River.[13] In 1882, Selwyn appointed Macoun to a permanent position as Dominion Botanist with the Museum Branch of the Geological Survey. Five years later, he attained the rank of Survey Naturalist and Assistant Director, with responsibility for developing a comprehensive inventory of the plant and animal life of the second largest country in the world.[14] The task would occupy him, as well as his son and assistant, James Macoun, and William Spreadborough, collector and field technician, until his death in 1920. It put him in contact with a wide variety of other naturalists, among them Thomas McIlwraith of Hamilton, whose 1886 work on the birds of Ontario[15] was probably the first annotated provincial bird book in Canada. John Macoun acknowledged the value of such correspondents in his introduction to the *Catalogue of Canadian Birds*, a monumental work that was published as a Geological Survey bulletin.[16]

A corollary to the expeditions of discovery during the late 19th century was the recognition that western Canada was endowed with landscapes of breathtaking beauty. The thought that scenery, as well as game, might be worth protecting was given tangible expression in 1887 with the adoption of the Rocky Mountains Park Act.[17] By this legislation, the Parliament of Canada created the first "Dominion Park," incorporating lands surrounding the Banff Hot Springs. In the same year, at the urging of Edgar Dewdney, Lieutenant-Governor of the Northwest Territories, the first dedicated wildlife sanctuary in Canada was established at Long Lake (now Last Mountain Lake, Saskatchewan).[18] In 1888 and 1895, additional reserves of land were set aside that would eventually, in 1911, become Glacier, Yoho, and Waterton Lakes national parks. Provincial governments also turned their attention to the preservation of prime recreational wilderness sites, such as Algonquin Park in Ontario (1893) and Quebec's Mont Tremblant and Laurentide parks (1894).

Generally, however, the political will to create national parks and park reserves in those days was more closely linked to economic development and the stimulation of tourist traffic for the Canadian Pacific Railway than to the preservation of wildlife habitat.[19] Early park managers were preoccupied with the construction of roads, bath houses, and hotels. Wildlife, in the opinion of some, was of interest only to the degree that hunting under regulation was deemed to enhance the attractiveness of the holiday destination. Indeed, when W. F. Whitcher, formerly Dominion Fisheries Commissioner, was asked to assess the wildlife of the Rocky Mountains Park reserve in 1886, he recommended that the "lupine, vulpine, feline vermin that prey on furred and feathered game" be exterminated.[20] Whitcher's view did not prevail, however, and an Order-in-Council of 1890 actually prohibited all killing of animals within the park with the exception of the removal, under authority of the Superintendent, of identifiably "troublesome" animals.

With the appointment of Howard Douglas as Superintendent of Rocky Mountains Park in 1897, the conservation of wildlife gained importance in the federal park. Douglas recognized that many park visitors were anxious to see wild animals in a setting approximating their natural habitat. He was deeply committed to strict enforcement of game protection within park boundaries, arguing that the wildlife, as the property of the state, must be preserved, and that members of the public must be educated to appreciate this concept of value and public good. As an early proponent of "ecotourism" as the key that would ensure sustained government support for parks, he worked to make the park both a refuge for native species and a zoo.[21]

The bit firmly in his teeth at this point, Douglas next set in motion one of the most ambitious wildlife rescue schemes ever attempted in Canada. In 1906, he initiated a campaign of negotiation and lobbying to purchase several hundred "wild" Plains Bison from a Montana rancher named Michel Pablo and to move them north to a new park that would be established for the purpose. Douglas's promotion to the position of Commissioner of Parks, in 1908, must have helped him promote this enterprise, for in the same year a park was created at Wainwright, Alberta, to receive the animals. By 1911, a total of 703 Plains Bison had been shipped across the border to become the property of the government and people of Canada.[22]

Despite the flurry of activity surrounding the establishment and enhancement of parks, it is probably fair to describe the general state of wildlife conservation at the turn of the century as a rudimentary activity consisting of "a few mild statutory restrictions...enforced by general police officers, and random introductions of wildlife as desired."[23] Public interest in wildlife was on the rise, however, in both Canada and the United States, as evidenced by the proliferation of sportsmen's clubs and of books, magazines, and newspaper columns on the outdoors.

Among the most influential participants in this popular groundswell were Ernest Thompson Seton and Charles G. D. Roberts. Between them, the two writers virtually invented that most Canadian of literary genres, the animal story. Both were keen outdoorsmen. By combining first-hand observation of animal behaviour with a certain latitude in attributing human emotional and intellectual responses to their animal subjects, they found a formula for best-selling success. Roberts was the author of more than a dozen collections of short stories that positioned wildlife sympathetically in the public consciousness. Seton, who enjoyed similar success, was an active lobbyist for conservation and a serious naturalist who would later publish *Mammals of Manitoba* (1909) and *The Arctic Prairies: A Canoe Journey of 2000 Miles in Search of the Caribou* (1911).[24]

Another great popularizer of wildlife at this time was Jack Miner, a transplanted American whose zeal for waterfowl led him to dedicate his property at Kingsville, Ontario, as a private bird sanctuary. Much in demand as a lecturer throughout Canada and the United States, he instilled a strong conservation ethic in many who heard him. It is a measure of his influence that the National Wildlife Week Act, passed by the House of Commons on 18 April 1947, stipulates that this public observance of the importance of wildlife should fall annually in the week of 10 April, Jack Miner's birthday.

Protective Measures

Political responses followed quickly on the heels of the newly identified public concern for wildlife. In 1905, the new provinces of Saskatchewan and Alberta entered Confederation, and in 1906, the Northwest Game Act was passed by Parliament to establish a framework for wildlife administration in those portions of the Northwest Territories that remained under federal jurisdiction. That year, too, Prince Edward Island adopted its first Game Act, and New Brunswick initiated the registration of hunting and fishing guides, a conservation and management tactic that other provinces later emulated. Jasper Forest Park of Canada[25] was created in 1907, and in 1909, Dominion Parks Commissioner Douglas instituted a force of park wardens to eliminate poaching in the lands under his direction. A little later, in 1913, the legislature of British Columbia passed its first Game Protection Act.

Probably the most significant legislative action on behalf of conservation at this time, however, was the Parliamentary adoption, on 19 May 1909, of the Act to Establish a Commission for the Conservation of Natural Resources. The Commission thus established consisted of 12 ministers of the Crown, eight members of university faculties, and 12 others. Its mandate was outlined in the Act as follows:

> It shall be the duty of the Commission to take into consideration all questions which may be brought to its notice relating to the conservation and better utilization of the natural resources of Canada, to make such inventories, collect and disseminate such information, conduct such investigations, inside and outside of Canada, and frame such recommendations as seem conducive to the accomplishment of that end.[26]

During its brief institutional lifetime, the Commission played an essential role in developing a framework for the governance of wildlife conservation in Canada. Its members were called upon "to study, investigate, and advise with respect to the conservation of natural resources and to be the embodiment of public spirit and advanced thought."[27] During the next 12 years, their political and intellectual skills were put to the test repeatedly. They played a critical role in the early stages of developing the Migratory Birds Convention, a treaty that has served ever since as a keystone of North American wildlife policy and protection. In addition, they contributed to the development of three basic wildlife acts: the National Parks Act, the Northwest Territories Game Act, and the Migratory Birds Convention Act.

A number of other appointments of crucial importance to Canadian wildlife conservation were made during this period. The first, in 1909, was that of Gordon C. Hewitt as Dominion Entomologist in the Department of Agriculture. As a university-trained scientist, Hewitt was one of a new breed in a public service in which many of the senior officials concerned with wildlife, such as John Macoun, were generalists — intelligent, passionately dedicated, eclectic in their scientific interests, but largely self-taught. Hewitt's expertise and credibility in scientific and political spheres, both in Ottawa and in Washington, were to be of critical importance in the years to come.

In 1911, Percy Algernon Taverner, taxidermist, architectural draughtsman, and the epitome of the self-taught amateur naturalist, was appointed to a position that John Macoun had long argued should be filled — that of staff ornithologist at the National Museum. He was 35 years old, and he was to remain with the Museum until 1942, dogged at times by the scorn of others for his lack of formal scientific training, but profoundly influencing the course of Canadian ornithology for a generation and more.[28]

Also in 1911, a decision was made to grant full branch status to the administration of national parks within the Department of the Interior. Howard Douglas was on the verge of retirement. His successor, and the first Dominion Parks Commissioner, was James Harkin. A journalist by profession, Harkin had, since 1903, served as Private Secretary to two successive Ministers of the Interior in the Laurier Cabinet, the Honourable Clifford Sifton and the Honourable Frank Oliver. Although he had no training in parks management, he was an astute political analyst and communicator. Also, since Sifton was now Chairman of the Conservation Commission and Oliver was one of the Commissioners (as well as Harkin's Minister), the new head of Parks was well connected when it came to getting things done.

Another attribute that Harkin brought to his new job was his commitment to a philosophy of parks that bordered on the mystical. He was deeply influenced by the writings of the American conservationist John Muir, and he believed fervently in the recreational, aesthetic, and spiritual values of unspoiled wilderness. In a prophetic mode, he wrote to Oliver:

> The day will come when the population of Canada will be ten times as great as it is now but the national parks ensure that every Canadian...will still have free access to vast areas possessing some of the finest scenery in Canada, in which the beauty of the landscape is protected from profanation, the natural wild animals, plants preserved, and the peace and solitude of primeval nature retained.[29]

Hewitt, Taverner, and Harkin were to be among the most important participants in the next phase of wildlife conservation in Canada. The first indications of things to come, however, did not involve them directly. Rather, they were expressed by a retired military man and historian, Lieutenant-Colonel William Wood of Quebec, who became deeply concerned about the disappearance of wildlife along the north shore of the Gulf of St. Lawrence. In 1912, having published several articles and books on the subject, he sought a more public forum, addressing the Canadian Club of Ottawa on the topic "Our Kindred of the Wild and How We Are Losing Them in Labrador."

The following year (1913), Wood pursued his theme further, with a formal presentation to the Conservation Commission. His recommendation was that the Commission itself should assume responsibility for protection of seabirds in the Gulf, close the region to hunting and egging, and establish island seabird sanctuaries. He named Percé/Bonaventure Island and Bird Rocks as candidate sites for such designation. To ensure that his proposals would be taken seriously, Wood had enlisted an impressive list of supporters. Among those who weighed in with letters to the Commission were Dr. John Clarke, Director of the New York State Museum, Ernest Thompson Seton, President Theodore Roosevelt, and His Royal Highness the Duke of Connaught, third son of the late Queen Victoria and Governor General of Canada.[30]

Diplomacy

The readiness of prestigious Americans to become involved in Canadian conservation issues was a sign of the extent to which the issue of conservation had captured the hearts and minds of the public in the United States. Pressure was increasing in Washington to achieve continental protection for migratory birds, and a treaty with Canada was perceived as one of the best means of accomplishing this in a way that would be proof against court challenges from individual states. Well aware that such a treaty might be the only way to acquire the authority for federal enforcement of national compliance in Canada as well, James Harkin initiated discussions with James Macoun and Percy Taverner to develop a consistent Canadian position. Gordon Hewitt, meanwhile, opened communications with the United States Biological Service in Washington and began sounding out the provincial authorities for their reactions.[31]

In 1914, the United States forwarded a draft migratory bird treaty to Ottawa for Canadian consideration. In due course it was circulated to the provinces. Most expressed support in principle, although Nova Scotia and British Columbia were openly doubtful, especially about restrictions on spring waterfowl hunting. New Brunswick's Lieutenant-Governor, Josiah Wood of Sackville, sent a guarded response, noting the potential for conflict about federal intrusion into a matter of provincial jurisdiction.[32]

If a reminder were needed that birds were at risk in Canada, it was supplied by no less likely a source than the federal government's own fisheries department, in the form of a demand that the Percé cormorant colony be exterminated on grounds that the birds were a threat to fish stocks. Hewitt and Taverner reacted quickly, advising the Honourable John Hazen, Minister of Marine and Fisheries, to rescind the order. Hazen, who was immediate Past President of the North American Fish and Game Protective Association, was not insensitive to the public relations pitfalls of the situation. He granted a stay of execution, which allowed Taverner time for a field trip to Percé to evaluate the alleged threat. The ornithologist found no sign of seabird depredations on the local fishery, but ample evidence that local fishermen were wantonly destroying eggs and slaughtering young and adult seabirds in great numbers. Horrified by what he had seen, Taverner told Harkin that both sites should be preserved as either bird sanctuaries or national parks and forwarded the same recommendation to James White, Secretary of the Conservation Commission. Early in 1915, Taverner and Gordon Hewitt, supported once again by Dr. John Clarke of the New York State Museum, presented papers to the annual meeting of the Commission, repeating William Wood's proposal for sanctuary status for both sites, and for Bird Rocks as well. Over the next four years, the sites were acquired, and in 1919, all were designated as sanctuaries under both federal and provincial law.[33]

Meanwhile, based on generally favourable reactions of the provinces to the draft treaty, the federal government indicated, by Order-in-Council, its agreement with the principle of international protection for migratory birds.[34] In August 1916, the International Treaty for the Protection of Migratory Birds (referred to subsequently as the Migratory Birds Convention) was signed by representatives of the two powers. The serious work of migratory bird protection on a continental scale could begin.

The next step to be taken in Ottawa's progress towards an integrated wildlife policy was the establishment of the Advisory Board on Wildlife Management, an interdepartmental committee of public servants who were expected to review and advise on questions relating to the management of migratory birds and of wildlife in general in the Northwest Territories. James Harkin represented the Parks Branch of the Department of the Interior on this body; Gordon Hewitt was the Agriculture representative; James White, secretary to the Conservation Commission, Rudolph Anderson, a zoologist with the Geological Survey, and Duncan Campbell Scott of Indian Affairs were the other members. By providing a forum in which to exchange information and analyses, the board tended to stabilize wildlife management policies from one department to another and to provide a common sense of direction. Among the items appearing on early agendas were Bison management, Caribou as an indigenous food source, preservation of Pronghorn Antelope, Elk population management, control of Wolves and other predators, and game sanctuaries.[35]

One of the first matters to which the Advisory Board turned its attention, however, was the drafting and implementation of the Migratory Birds Convention Act (1917). This was the enabling legislation that would turn the good intentions of the Convention with Washington into a practical law and regulations, empowering the federal government to protect migratory birds and regulate hunting. To administer it, a Migratory Birds Section was to be established within the Parks Branch. In the interests of consolidating responsibilities, the Parks Branch was also given the task of administering the Northwest Game Act (1917) and all wildlife administration in the Northwest Territories.

Once again, as in the case of the Convention itself, the active participation of the provinces was deemed to be crucial to success, and once again it was somewhat problematical. British Columbia had been the principal holdout in the earlier negotiations, but relatively soon after passage of the Migratory Birds Convention Act it joined with Alberta, Saskatchewan, Manitoba, Ontario, and Quebec in amending its provincial game laws to conform to the new international rules. It was in the east that provincial opposition became something of a problem.[36] New Brunswick repealed its waterfowl legislation on the grounds that, since migratory birds were now a federal responsibility, the province need do nothing to protect them. Nova Scotia took a similar, if less extreme, position. Prince Edward Island did not address the jurisdictional question except indirectly, complaining that it lacked the wardens to provide enforcement of the law. In view of these responses, it seemed evident that the federal government would have to appoint its own enforcement officers, at least in the Maritimes.

In 1918, therefore, Hoyes Lloyd, a chemist by profession but an ornithologist by avocation, was appointed as ornithologist and administrator of the Migratory Birds Regulations. The position was situated within the Wildlife Division of the Parks Branch, was answerable to James Harkin, and paid a salary of $2200 per annum.[37]

Getting Started

Lloyd, a true enthusiast of birds and natural history, found himself part of a small group of like-minded men who shared a strong sense of mission. He joined Harkin and Hewitt as a tireless spokesman for wildlife conservation and, like Taverner, wrote numerous articles and pamphlets to promote public awareness and support.

He barely had time to get settled into his new job, however, when it was expanded by his appointment to the more exalted position of Supervisor of Wild Life Protection in Canada, with responsibility for administering the Northwest Game Act as well as the Migratory Birds Convention Act.

> He had to administer two new acts, both very different from the legislation that had preceded them. He had to organize a comprehensive publicity campaign, aimed at making popular these new laws, which in several quarters were distinctly unpopular. He had to lay the foundations for cooperation with the game authorities of nine provinces and with the authorities who were his opposite numbers in the United States. He had to plan, select, and organize a system of important national waterfowl sanctuaries. And he had to take an active part, not only in organizing a staff of game officers, honorary and salaried, but in the actual application and enforcement of these laws, so that by a number of well publicized convictions and penalties it might be evident to all concerned that this new legislation was actually effective.[38]

Lloyd lost no time in getting on with the job. During the first year in his expanded role, he had to deal with the repercussions of a decision to permit limited hunting in the newly established Point Pelee National Park, as well as the creation of seabird sanctuaries at Percé and Bonaventure Island and at Bird Rocks, the appointment of Canada's first Migratory Bird Officers, and the coordination of a National Conference on the Conservation of Game.

The Conservation Conference of 1919 brought together the Advisory Board, the Conservation Commission, and representatives from the provinces,

A monument to both the destruction and the restoration of colonial seabirds and formerly the nesting site of as many as 100 000 Northern Gannets, Bird Rocks in the Gulf of St. Lawrence became a Migratory Bird Sanctuary in 1919, thanks to the efforts of Gordon Hewitt and Percy A. Taverner (Photo credit: A. Smith).

the United States, and a variety of nongovernment organizations. Opening the gathering, the Honourable Arthur Meighen, Minister of the Interior in the Union government of Sir Robert Borden, stated:

> We have only realized very late...that the conservation of our game is as vital a subject for consideration and attention as is the conservation of any other of our natural resources.[39]

Ironically, Meighen, as a newly elected Conservative Prime Minister, would disband the Conservation Commission just two years later,[40] citing its independence from departmental authority:

> I do not think it is consistent with our system of government that there should be a body for which no one is answerable, and over which no one has any control, as is the case with this commission.[41]

Gordon Hewitt died prematurely in 1920 at the age of 36, leaving his book, *The Conservation of the Wild Life of Canada*,[42] to be published posthumously a year later. In 1919, however, such considerations were not on the agenda. Hewitt took a leading role at the Conference, urging foresight and national and international cooperation in conservation.[43] A proposal was put forward to repeat the conference annually. Although this did not happen, the event was a precursor of annual federal–provincial wildlife meetings in later years.

In purely practical terms, the most important accomplishment of Hoyes Lloyd's first year as Superintendent of Wild Life Protection was probably the appointment of Canada's first Migratory Bird Officers. The refusal or inability of the Maritime provinces to collaborate in enforcing the Migratory Birds Regulations determined where the resources would be allocated. Robie W. Tufts, of Wolfville, Nova Scotia, became Chief Migratory Bird Officer, with five seasonal juniors working under his direction.

Initially, Lloyd coordinated the work of his division in the rest of Canada, successfully negotiating the establishment of several bird sanctuaries in the west. In 1920, to augment the efforts of provincial wardens in the six fully participating provinces, he arranged that all Royal Canadian Mounted Police (RCMP) officers should become ex officio game officers under the terms of the Migratory Birds Convention Act.[44] In addition, he instituted a network of Honorary Federal Game Officers, largely as a public relations force to promote conservation values and compliance with the law.

It was clear, however, that more resources were required. In November 1920, two additional Chief Migratory Bird Officers were named. Harrison F. Lewis was assigned to oversee conservation and enforcement activities in Ontario and Quebec. James (Jim) A. Munro, who had been the other candidate for Lloyd's position in 1918, received a similar commission for British Columbia and the Prairies. Each was to receive an annual salary of $1500. The appointment made each of them not only a peace officer with the arresting powers of a police constable, but also a Justice of the Peace with the power to hear and adjudicate summary conviction cases under the Act. Lewis later recalled James Harkin's injunction at the close of his first interview following the appointment: "Now remember. You are on duty twenty-four hours a day — and twenty-five if we need you!"[45]

Fieldwork

The Chief Migratory Bird Officers set about their tasks with a will, speaking on the new conservation laws wherever they could get an audience, pressing charges against poachers, investigating potential sites for bird sanctuaries, inspecting taxidermists' shops, distributing educational materials, and issuing possession permits to scientific collectors and aviculturists. On occasion, they found themselves dealing with situations where the comic element threatened to overwhelm the seriousness of the law. One of Robie Tufts' assistant officers, for example, had charged the A. & R. Loggie Company with the purchase and sale of wild geese at their general store in South Kouchibouguac, New Brunswick. The officer, B. S. Colbran, posing as a travelling salesman, had asked if they had any birds. The store manager led him to the walk-in freezer where 50 or more Canada Geese and Brant were strung up along the wall. Colbran promptly showed his badge and seized the evidence. The next morning, the defendant appeared before the local magistrate, Leon Daigle. When a fine of $300 was levied, the unhappy manager winced and pleaded, "Your Honour, this is my first offence. Can't you do a little better for me?" The magistrate, a sympathetic frown on his face, replied, "Well, the Act here says $300. If it said $500, I could do that much better for you."[46]

Harrison Lewis, meanwhile, had acquired a boat, the *Perroquet*, to enable him to patrol the multitude of islands that hugged the north shore of the Gulf of St. Lawrence. Here, he was unwavering in his pursuit of poachers and, given the isolation of this part of his territory, often found himself in potentially awkward situations. Fortunately, as F. Graham Cooch would recall many years later, "His second name was Flint, and so was his nature."[47]

On one occasion, Lewis discovered two men taking eider eggs on one of the Mingan Islands and staked out their rowboat to await their return. He was hidden behind a stack of firewood when the situation was suddenly complicated by the arrival of a second boat with two men who had come to take the firewood back to the mainland. As they worked, Lewis's hiding place grew steadily smaller and less secure, but their labours were delayed by the arrival of yet another man, a poacher no less, with a shotgun and a dog. The dog was a new source of worry:

It was clear that his nose was telling him about something he could not see. Sniffing for guidance, he was seeking the source of the scent — my scent! Up and over the woodpile his nose was guiding him. I could hear his claws scratching the bark as he came across the wood. Looking up from my crouched position, I saw his muzzle....Just when I felt all was lost, the dog's muzzle disappeared! A moment later I heard his excited barking as he raced northward along the beach. It could only mean one thing. In the very nick of time, the two men with the buckets must have issued from the woods a little distance away and the dog had hastened to meet them. Shortly it became evident that these two had reached the group in front of the woodpile and had paused there to join in the conversation. Now was the time for action!...I placed a foot on top of the reduced woodpile and with one more stride I was in their midst. Their surprise was complete.

I took out notebook and pencil and asked one of the two egg-gatherers his name. While he was pulling himself together and trying to think of an acceptable false name, his partner suddenly made a dash for their boat. Every man for himself was evidently his motto. He was sadly disappointed to find [I had made the boat fast with] difficult knots which could not be untied in a hurry. To put an end to that sort of thing, I went to the boat and sat in it. Then I ordered the egg-collectors to bring the buckets full of eggs and place them in the boat and to untie the painter and get into the boat themselves. All of this they obediently did.

I told them to row around into the harbour and go alongside my anchored boat....When we reached the *Perroquet* with the boatman on board and our tender trailing astern, I told the eggers to appear before the local Justice of the Peace at ten o'clock the next morning as I should then be there to settle the matter. Then my boatman took them in our tender to the village, leaving their boat and the eggs with me on the *Perroquet*. I really enjoyed my breakfast that morning.[48]

Imperturbable game officer though he might be, Lewis's real passion was for ornithology. The summer of 1923 must have been idyllic for him. With a boat at his disposal and all the seabirds of the north shore awaiting discovery and description, he was in his element.

His excitement one day in July could scarcely be contained when he discovered Great Cormorants nesting on the face of a cliff on Île du Lac, between Baie des Loups and Îles Ste-Marie. Only a year earlier, the American ornithologist Arthur Cleveland Bent had issued the judgment, in his life history of the cormorants, that this species was "probably now extirpated as a breeding bird in North America."[49] Conscious of his status as a very junior ornithologist, Lewis clambered down the cliff-face until he could reach a nest with four large, half-fledged chicks, three of which he successfully banded. He knew that one of the distinguishing differences between Double-crested and Great cormorants is the number of tail feathers — 12 in the former species and 14 in the latter. Carefully, he counted the feathers. Fourteen. There was no doubt of the identification.[50]

To discover active nests of a species that someone of Bent's stature had decreed extirpated was an ornithological coup, but Lewis's satisfaction was also enhanced by his keen sense of history. His discovery occurred in the very vicinity where, 90 years earlier, Audubon himself had observed the nurturing behaviour of a female Great Cormorant towards her young. One outcome of this event may well have been the ignition of Lewis's particular interest in cormorants, which led, six years later, to his acquisition of a Ph.D. from Cornell University and to the publication of his monograph, *The Natural History of the Double-crested Cormorant*, a work that is still cited in the literature today.[51]

If a territory comprising all of Ontario and Quebec seemed large for a single officer, it was surpassed by Jim Munro's beat, which encompassed not only the four western provinces but the Northwest Territories as well. A marginally more practical solution to this challenge was found by subdividing. Munro concentrated his efforts in British Columbia and Alberta. Here, he not only coordinated conservation and enforcement activities, but also conducted an ongoing research program that enabled him, over several years, to publish more than a dozen titles in the series *Studies of Waterfowl in British Columbia.* West coast fishermen, like their east coast counterparts, were highly suspicious of waterfowl as serious competitors for fish stocks. Munro's studies to determine whether or not ducks and gulls consumed enough salmon eggs to diminish the size of returning spawning runs in various watersheds represented another major time commitment.

Hoyes Lloyd, meanwhile, undertook to cover Manitoba and Saskatchewan, gathering important data on prairie waterfowl distribution and breeding habitat and carrying the conservation message to the communities he visited. Some sense of the energy that he and his colleagues devoted to public relations and proselytizing can be inferred from the fact that, in 1924 alone, Lloyd, Munro, Lewis, and Tufts gave a collective total of 452 public lectures.

Bison Politics

Prairie waterfowl were not the only topic to command Lloyd's attention in the 1920s.

As early as 1911, James Harkin had been working with Maxwell Graham, Chief of the Animal Division in the Parks Branch, to establish a haven for Canada's remnant population of Wood Bison. In 1922, their efforts were rewarded with the establishment of Wood Buffalo Park.[52] In that vast tract of land sprawling across northern Alberta and into the Northwest Territories, the future of the shaggy creatures seemed to be assured.

Bison were important symbols for the conservation movement. Howard Douglas's "rescue" and transfer of hundreds of Plains Bison from Montana to Alberta more than a decade earlier had captured the Canadian imagination. To all appearances, the Wainwright herd was thriving — so well, in fact, that in 1924 it was decided to relieve pressure on the available range by making a selective cull of 250 animals. What was supposed to have been a routine management measure assumed more ominous proportions when a postmortem inspection of the carcasses revealed that 199 of them had tuberculosis lesions.[53]

In the best interest of the species, and of epidemiological control, a program of testing, quarantine, and the elimination of diseased Bison would seem to have been the wisest way to proceed, but this was not the option chosen. Perhaps common sense was hampered by the fear that a public outcry might ensue if there were a wholesale slaughter of the icons of conservation. Rather, in the December 1924 issue of the *Canadian Field-Naturalist*, there appeared a brief article by Maxwell Graham, then Chief of the Animal Division of the Parks Branch, entitled "Finding Range for Canada's Buffalo." In it, he proposed that some 1000 to 2000 Plains Bison be rounded up annually and shipped to Wood Buffalo National Park because there was insufficient pasture and forage at Wainwright. The article made no mention of disease.[54]

It did not take long for a contrary view to find expression. On 14 February 1925, Dr. Francis Harper of the Zoological Laboratory at Cornell University wrote an eloquent letter of protest to the *Canadian Field-Naturalist*, praising the value of Wood Buffalo National Park as a refuge for the last known herd of Wood Bison. He noted that the subspecies for which the park was named was on the way to a most promising recovery, having increased from about 300 in 1907 to an estimated 1500 in 1924. It would be folly, he argued, to submerge the pure northern strain in a flood of Plains Bison. Interbreeding and the introduction of disease into a healthy population were sufficient reasons not to adopt Graham's proposal.[55]

What happened next is best told in the words of Harrison Lewis:

> It happened that, at that time, Hoyes Lloyd was President of the Ottawa Field-Naturalists' Club and I was Editor of *The Canadian Field-Naturalist*. Dr. Francis Harper was a well known and reputable zoologist; his letter was straightforward and to the point, and it was published in the February issue of *The Canadian Field-Naturalist* as a matter of course.
>
> The minutes of a meeting of the Ottawa Field-Naturalists' Club held on February 28, 1925, show that President Hoyes Lloyd presided, and contain the following entry:
>
> > The question of the advisability of moving plains buffalo north to home of woods [sic] buffalo was introduced. Mr. Lewis moved, Mr. Sternberg seconded that the Secretary send a copy of the Feb. Naturalist to the Minister of the Interior accompanied by a letter stating that the Council of the Club was unanimously against the planned project of moving plains buffalo north from Wainwright to Fort Smith, the home of the wood buffalo. By this move we consider the government would be negating their own action of setting aside a national park for the northern wood buffalo.
>
> A month or so later, Mr. Lloyd and I were notified that we could either resign our respective positions with the Field-Naturalists' Club and its magazine or be expelled from the Department of the Interior.[56]

In the face of this ultimatum, Lloyd and Lewis resigned their club duties, and, although the May issue of the *Field-Naturalist* contained more correspondence on the subject, including a resolution from the American Society of Mammalogists in support of Dr. Harper's position, the transfer of stock went ahead. In all, some 6673 animals were moved north to Wood Buffalo National Park between 1925 and 1928. The repercussions of that action continue to be felt to the present day (see Chapter 4).

While the politics of Bison management dominated the prairie agenda in 1925, a more positive development was coming to fruition in the east. After three years of exploration among the islands along the north shore of the Gulf of St. Lawrence, 10 sanctuaries proposed by Harrison Lewis were duly set aside under the Migratory Birds Convention Act. That summer, Lewis undertook the first comprehensive census of the seabird colonies within their boundaries. The same census has been repeated regularly, at roughly five-year intervals, ever since, giving rise to one of the longest continuous databases for colonial seabird studies in North America.[57]

Meanwhile, the Dominion Parks Branch was expanding its vision of wildlife management in another direction. Ever since the creation of Rocky Mountains (now Banff) Park in the 1880s, sport fishing had been attracting a high volume of tourist traffic to the national parks. Now, in 1928, Donald S. Rawson began investigating fish habitat and distribution in the parks in order to develop a better knowledge base for management of this activity.

The 1930s brought major new challenges to the guardians of Canada's wildlife. Starting in the summer of 1929, a series of disastrous years of drought devastated the prairie sloughs and potholes that were the breeding grounds for a large proportion of the ducks of the central migratory flyway. In the first year, waterfowl productivity in parts of Saskatchewan fell by about 90%.[58]

Two years later, Maritime populations of Brant were adversely affected by a serious die-off of Eelgrass. The tuberous roots of this plant of the coastal shallows and estuaries were a critically important food source in staging and wintering areas. By 1933, it was estimated that the fall migration of Brant in the Atlantic flyway had fallen to 5% of its previously normal size.[59]

Stresses tend to reverberate throughout ecosystems, and one unanticipated stress on wildlife all across Canada during the 1930s came from the human population. Economic depression, unemployment, and poverty increased the incentive for many to steal eggs or hunt game birds out of season. Mammals came under pressure as well, being hunted either for the table or to augment the meagre incomes of desperate people.

Coincidentally, 1934 brought a serious drop in the Gulf of St. Lawrence population of Capelin and Sand Lance, two fish species that occupy a vital position in the east coast marine food web. During his summer patrols, Lewis noted reduced breeding success among seabirds and an increase in the predation of Great Black-backed Gulls on young Common Eiders.[60]

By 1934, the growing pressures of administration had enabled Hoyes Lloyd to obtain approval for the appointment of a full-time Chief Migratory Birds Officer for the Prairies. The successful candidate was J. Dewey Soper, a naturalist-explorer who had undertaken a number of Arctic expeditions during the 1920s on behalf of the National Museum. On an extended mission during 1928–1929, he had won the attention of ornithologists by his discovery on Baffin Island of the nesting grounds, hitherto unknown to science, of the Blue Goose. The full extent of his accomplishment is best gauged from his own brief summary of the trek. In the course of 3700 kilometres travelled on foot, by dog team, and by canoe, he took 1650 map bearings, 99 latitude observations, and 560 observations of magnetic declination, correcting several serious errors of previous mapping expeditions in the area. He collected 513 scientific specimens of mammals, birds, and eggs, 177 insect specimens, and 62 sheets of plant specimens. He documented the outing in 539 photographs and filled 15 notebooks, as well as producing detailed catalogues and maps of his journey.[61]

Soper took up Lloyd's work on prairie nesting habitat at a propitious moment, as the concern of American sportsmen over the decline in waterfowl populations was beginning to be felt in Canada. In 1935, a private organization called More Game Birds in America Inc., a precursor of Ducks Unlimited, sponsored a breeding waterfowl survey in the prairies. Three years later, Ducks Unlimited (Canada) undertook its first prairie initiatives to restore and protect waterfowl breeding habitat, establishing what would become one of the dominant themes in wildlife conservation for the next 60 years.

As the decade advanced, more resources became available for wildlife work, and additional talented individuals became involved. In 1938, mammalogist C. H. D. Clarke transferred to the Wildlife Division from the staff of the National Museum and spent the next several years investigating wildlife and recommending big game management strategies for the mountain parks. This work was extended by Ian McTaggart-Cowan of the University of British Columbia, who, as early as 1930, had undertaken intermittent seasonal studies in the parks on behalf of the National Museum of Canada. In 1943, he began a series of wildlife investigations and reports, under contract to the Parks Branch, that would continue for many years.

One of the great scientist-explorers of the Canadian Arctic, Dewey Soper began working with the National Museum of Canada in the early 1920s, became Dominion Wildlife Officer for the Prairies in 1934, and was part of the original CWS team in 1947. A field man throughout his career, he visited Kendall Island, NWT, in August 1951, less than a year before his retirement, to observe the Snow Goose colony there (Photo credit: E. McEwan).

Meanwhile, Donald Rawson continued his consultative research on the lakes of prairie and mountain parks. He was joined in 1939 by Harold L. Rogers, the first full-time limnologist to be hired by the Parks Branch. Unfortunately, war broke out that autumn. Rogers joined the Royal Canadian Air Force and was killed two years later, in 1941. Limnological work was not resumed on a full-time basis until the appointment of Victor E. F. (Vic) Solman in 1945.

On 31 December 1943, Hoyes Lloyd retired, closing the door on 25 years in charge of federal protection of migratory birds and other wildlife. He had charted a remarkable career in both field biology and public administration. To his successor, Harrison Lewis, would fall the responsibility of gathering all the themes of the past quarter century and weaving them into a coherent agency for wildlife policy and protection.

Notes

1. W. A. Montevecchi and L. M. Tuck, *Newfoundland Birds: Exploitation, Study, Conservation* (Cambridge, Massachusetts: Nuttall Ornithological Club, 1987), page 47.
2. Nicolas Denys, *Description géographique et historique des costes de l'Amérique septentrionale* (originally written in 1672), edited and translated by William F. Ganong (Toronto: The Champlain Society, 1908), page 477.
3. George Cartwright, *Journal of Transactions and Events, during a Residence of Nearly Sixteen Years on the Coast of Labrador: Containing Many Interesting Particulars, both of the Country and its Inhabitants not Hitherto Known, Volume III* (1792), page 55 (from the entry for 5 July 1785); cited in David N. Nettleship and Tim R. Birkhead, *The Atlantic Alcidae* (London: Academic Press, 1985).
4. Janet Foster, *Working for Wildlife: The Beginning of Preservation in Canada* (Toronto: University of Toronto Press, 1978), page 184.
5. R. Tufts, *Birds of Nova Scotia*, revised edition (Halifax: Nimbus Publishing and the Nova Scotia Museum, 1986), page 50.
6. Gilles Chapdelaine, personal communication, Quebec City, March 1997.
7. John Palliser, *Explorations — British North America* (London: Queen's Printer, 1863); cited in Foster, *Working for Wildlife*, page 7. (See note 4)
8. D. Guay, *Histoires vraies de la chasse au Québec* (Montréal: VLB Éditeur, 1983).
9. Canada Department of Agriculture, *Canada: Its History, Productions and Natural Resources* (Ottawa, 1886).
10. Foster, *Working for Wildlife*, page 10. (See note 4)
11. cf. John Macoun, *The Autobiography of John Macoun, M.A., Canadian Explorer and Naturalist* [a memorial volume published by the Ottawa Field-Naturalists' Club in 1922], 2nd edition (annotated) (Ottawa: Canadian Field-Naturalist Special Publication, 1979).
12. W. A. Waiser, *The Field Naturalist: John Macoun, the Geological Survey, and Natural Science* (Toronto: University of Toronto Press, 1989).
13. M. Zaslow, *Reading the Rocks: The Story of the Geological Survey of Canada 1842–1972* (Toronto: Macmillan Company of Canada, 1975).
14. H. Ouellet, "Ornithology at Canada's National Museum" in W. E. Davis, Jr. and J. A. Jackson (editors), *Contributions to the History of North American Ornithology* (Cambridge, Massachusetts: Memoirs of the Nuttall Ornithological Club Number 12, 1995).
15. Thomas McIlwraith, *The Birds of Ontario: Being a List of Birds Observed in the Province of Ontario* (Hamilton, Ontario: The Hamilton Association, 1886).
16. John Macoun and James Macoun, *Catalogue of Canadian Birds* (Ottawa: Geological Survey of Canada Publication Number 973, 1915).
17. W. F. Lothian, *A History of Canada's National Parks, Volume I* (Ottawa: Parks Canada, 1976), page 26.
18. Foster, *Working for Wildlife*, page 179. (See note 4)
19. Foster, *Working for Wildlife*, pages 16ff. (See note 4)
20. Canada, Parliament, Sessional Papers Number 7, Mr. Whitcher's Report 86 (House of Commons, 1887); quoted in Foster, *Working for Wildlife*, page 28. (See note 4)
21. W. F. Lothian, *A History of Canada's National Parks, Volume IV* (Ottawa: Parks Canada, 1981), page 18.
22. Lothian, *A History, Volume IV*, pages 25ff. (See note 21)
23. Harrison F. Lewis, *Fifty Years of Progress and Handicaps in Wildlife Management in Canada* (Sackville, New Brunswick: Canadian Wildlife Service, Atlantic Region Library, unpublished manuscript, 1951), page 1.
24. N. Story, *The Oxford Companion to Canadian History and Literature* (Toronto: Oxford University Press, 1967), page 757.
25. Lothian, *A History, Volume I*, page 52. (See note 17)
26. Statutes of Canada, 8-9 Edward VII, Chapter 27, *An Act to Establish a Commission for the Conservation of Natural Resources* (Ottawa, 1909).
27. Lewis, *Fifty Years of Progress*, page 6. (See note 23)
28. For a comprehensive treatment of Taverner's life and contributions to Canadian ornithology, see John L. Cranmer-Byng, "A Life with Birds: Percy A. Taverner, Canadian Ornithologist, 1875–1947," *The Canadian Field-Naturalist* 110(1): 1–254 (1996), Special Issue.
29. Quoted in Mabel B. Williams, *The History and Meaning of National Parks in Canada* (Saskatoon: H. R. Lawson Publishing, 1957), page 9.
30. Foster, *Working for Wildlife*, pages 182–183. (See note 4)
31. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), pages 12–13.
32. Foster, *Working for Wildlife*, page 135. (See note 4)
33. Foster, *Working for Wildlife*, page 189. (See note 4)
34. Order-in-Council P.C. 1247, 15 May 1915.
35. Foster, *Working for Wildlife*, page 163. (See note 4)
36. Foster, *Working for Wildlife*, page 155. (See note 4)
37. Lewis, *Lively*, page 19. (See note 31)
38. Lewis, *Lively*, page 20. (See note 31)
39. Quoted in Foster, *Working for Wildlife*, page 3. (See note 4)
40. Statutes of Canada, 11-12 George V, Chapter 23, *An Act to Repeal the Conservation Act and Amendments* (Ottawa, 1921).
41. Dominion of Canada, *Official Report of Debates of the House of Commons*, Fifth Session, Thirteenth Parliament, 11-12 George V, 26 May 1921. Debate on the bill, largely between the Prime Minister and the Honourable Dr. Henri Béland, Member of Parliament for Beauce and a member of the Commission since its inception, occupied fully 12 pages of *Hansard*. Although Meighen acknowledged that the Commission might have accomplished some useful tasks in its early years, he maintained strenuously that it had "gone about in one direction or another, laying its hand on anything that looked alluring, anything that could be regarded as a possible field of activity, [invading] the province of one department of government after another, and necessarily [duplicating] services wherever it has so invaded."
42. Gordon C. Hewitt, *The Conservation of the Wild Life of Canada* (New York: Scribner's Sons, 1921).
43. Foster, *Working for Wildlife*, page 201. (See note 4)
44. Lewis, *Lively*, page 24. (See note 31)

45. Lewis, *Lively*, page 26. (See note 31)
46. Robie W. Tufts, *Looking Back: Recollections of a Migratory Bird Officer* (Windsor, Nova Scotia: Lancelot Press, 1975).
47. F. Graham Cooch, personal communication, 1997.
48. Lewis, *Lively*, pages 78ff. (See note 31)
49. A. C. Bent, *Life Histories of North American Petrels and Pelicans and their Allies* (United States National Museum Bulletin Number 121, 1922; Dover Publications reprint, 1964).
50. Bent, *Life Histories*, page 88. (See note 49)
51. H. F. Lewis, *The Natural History of the Double-crested Cormorant* (Ottawa: Ru-Mi-Lou Books, 1929).
52. Order-in-Council P.C. 2498, 18 December 1922.
53. C. Gates, T. Chowns, and H. Reynolds, "Wood buffalo at the crossroads" in John Foster and Dick Harrison (editors), *Buffalo*, published as *Alberta: Studies in the Arts and Sciences* 3(1) (Edmonton: University of Alberta Press, 1992).
54. M. Graham, "Finding range for Canada's buffalo," *The Canadian Field-Naturalist* 38: 189 (1924).
55. Francis Harper, Letter to the Editor, *The Canadian Field-Naturalist* 39: 45 (1925).
56. Lewis, *Lively*, page 113. (See note 31)
57. G. Chapdelaine, "Fourteenth census of seabird populations in the sanctuaries of the North Shore of the Gulf of St. Lawrence, 1993," *The Canadian Field-Naturalist* 109(2): 220–226 (1995).
58. Lewis, *Lively*, page 136. (See note 31)
59. Lewis, *Lively*, page 136. (See note 31)
60. Lewis, *Lively*, pages 172ff. (See note 31)
61. J. Dewey Soper, *Explorations in Southwestern Baffin Island*, revised report (Canadian Wildlife Service Archive, Document Number 3, unpublished manuscript, 1951).

1947–1952: Setting the Wildlife Service Agenda

By the implementation of Order-in-Council P.C. 37/4433, the Government of Canada reorganized the Department of Resources and Development and charged a new agency, the Dominion Wildlife Service, with most of the federal responsibilities for wildlife management in Canada. Management was a key word, as the National Museum of Canada continued to exercise an important research role with regard to wildlife and ecological studies.

When the Dominion Wildlife Service officially came into being on 1 November 1947, the move came as no great surprise. In his unpublished history of the Canadian Wildlife Service (CWS), Harrison Lewis noted:

> ...there is evidence that I had some forewarning of impending change, for, under date of October 17, 1947, my official diary contains the entry, "Prepared a chart of organization of proposed Dominion Wildlife Service."...It came out clearly, however, that our small existing field staff, with a heavy load of administrative and liaison responsibilities, could not possibly acquire by field studies the scientific data that would be required to improve the protection of migratory birds in some important particulars.[1]

At the outset, the new service employed fewer than 30 people, including personnel from the former Migratory Birds Unit, the former Forest and Wildlife Conservation Section, the former Wildlife Division of the National Parks Bureau, and the wildlife management component of the former Bureau of Northwest Territories and Yukon Affairs. Small the team might be, but it had real depth of experience. Like Lewis himself, Jim Munro in British Columbia, Dewey Soper in the Prairies, and Robie Tufts in the Maritimes had worked for many years. These former Chief Migratory Bird Officers now bore the more general title of Dominion Wildlife Officer in their respective territories. Other seasoned field scientists included ornithologists Oliver H. Hewitt and George F. ("Joe") Boyer, mammalogists A. W. F. (Frank) Banfield, W. A. (Bill) Fuller, and Ward E. Stevens, and limnologist Vic Solman.

In addition, a rising generation of younger biologists was beginning to make its presence felt. Reports of the mid-1940s include references to student assistants Graham Cooch, John P. Kelsall, Louis Lemieux, David A. Munro (son of Jim Munro), and John S. Tener, individuals who would all have a formative influence on the agency as they attained permanent positions.

Interestingly, despite the high proportion of scientifically trained employees, the term "research" did not figure largely in early job descriptions. Indeed, R. A. Gibson, writing to Harrison Lewis on 14 November 1947, stressed that:

As the sole Dominion Wildlife Officer for the Maritimes in the early years of CWS, Joe Boyer fulfilled duties that ranged from harvest surveys to the banding of Bank Swallows (in this 1952 photograph) (Photo credit: CWS).

> The Mines, Forests and Scientific Services Branch is designed to include the basic research activities of the department....The name of our new Branch is the Lands and Development Services Branch. In contrast with the research organization, ours is to be primarily a development and administrative service.[2]

Just how seriously this admonition was taken can be inferred from Lewis's own wry comment:

> This, it seems, was simply following the official line and reminding me to follow it, too. We certainly did diligent investigation and added to human knowledge, and we had to do work of this kind more and more, as time went on, because of the great need for it and because no other part of the government service was prepared to obtain the sort of information that we required for efficient wildlife management.[3]

That the imprecision of the mandate conferred a precious freedom of scope and action on the new service was a point not missed by Lewis, nor by his colleagues and successors. Science and politics respond to different imperatives, and many of the outstanding scientific and conservation achievements of the Wildlife Service over its first 50 years can reasonably be attributed to the maintenance of a healthy distance between field research and the political arena. Nevertheless, a general frame of reference was required. Gibson outlined one in a letter dated 14 November 1947:

> The Dominion Wildlife Service deals with questions of policy and method with respect to conservation and management of those wildlife resources that are under control of the Dominion Government, including furbearers, game, and other wild animals and birds, and will obtain by scientific research, the information necessary for such conservation and management. Specific items in the class outlined will include administration of the Migratory Birds Convention Act, and the Northwest Game Act and Fur Export Ordinance, conservation of the game and fur resources and other wild creatures in the Northwest Territories, management of wild animals, birds and fish in the National Parks of Canada, handling of national and international problems relating to wildlife resources as a national asset, co-operation with other agencies having similar interests and problems, and planning and carrying out scientific investigations relating to numbers, food, shelter, migrations, reproduction, diseases, parasites, predators, competitors, and uses of the wild creatures that constitute the resources being managed.[4]

Even with limited resources, an enterprising group of biologists could accomplish an impressive amount of work under that mandate. During the first year, Frank Banfield, Chief Mammalogist, and subsequently author of *Mammals of Canada*, coordinated the launch of a multi-year investigation into the status, range, and general ecology of the Barren-ground Caribou.[5] Fuller and Stevens concentrated largely on the biological and economic significance of Muskrats in the Northwest Territories, although Fuller also produced and submitted reports on Beaver, Marten, Elk, Bison, Wolves, and Caribou during the course of the year. Solman, the limnologist, conducted studies of fish populations and ecology in 34 lakes and eight streams in nine national parks. Meanwhile, other staff biologists were at work all across Canada, gathering data about Snow Geese on the shores of Hudson Bay, woodcock and snipe in southern Ontario, Sandhill Cranes in the Prairies, and waterfowl from British Columbia to the Maritimes.

Clearly, though, there was far more work to be done than staff to do it. As early as 31 October 1947, Lewis and Gibson had discussed personnel requirements with Hugh Keenleyside, Deputy Minister of Mines and Resources. It did not take long to convince the Deputy Minister that additional strength was needed. Before the encounter ended, Lewis had a commitment for the appointment of four additional biologists — one each for the Maritimes, Ontario/Quebec, the Prairies, and British Columbia.[6] The new appointees would be called Wildlife Management Officers and would focus particularly on the conduct of surveys, studies, and investigations into wildlife populations.

Because of the small size of the staff, appointments made at this time influenced the Wildlife Service profoundly for many years to come. David Munro became Wildlife Management Officer for British Columbia, while John Tener was appointed to a similar position in Ontario; each would eventually head the agency. Another former student assistant, John Kelsall, passed the spring of 1948 evaluating Moose habitat in Cape Breton Highlands National Park and surveying general conditions for wildlife in Fundy National Park, before being sent to the Arctic in July to conduct wildlife surveys and collect specimens. In September, Kelsall was named mammalogist for the eastern Arctic. In Ottawa, Jean-Paul Cuerrier was hired to assist Vic Solman and became senior limnologist when Solman was promoted to the position of Chief Biologist.

The splitting of the enormous Prairie region into two sections resulted in Dewey Soper's being assigned to open a new office in Edmonton, while D. G. Colls and J. Bernard (Bernie) Gollop were appointed Dominion Wildlife Officer and Wildlife Management Officer, respectively, for Manitoba and Saskatchewan. Jim Munro retired after 29 years of public service and was succeeded by R. H. (Ron) Mackay on the west coast. In Ontario, Oliver Hewitt resigned in December 1948 to take up a faculty position at Cornell University and was replaced by George Stirrett.

The pace of growth experienced by the Dominion Wildlife Service in its early years remained relatively gradual. It was fortunate that traffic between the halls of government and academe could flow in both directions. In order to expand the range and scope of field projects, university professors were often enlisted as collaborators and contractors during the nonacademic

In April 1952, Harrison F. Lewis retired. Those attending the farewell gathering and presentation included: (*front row, l. to r.*) Phyllis Scharf, Roger Haspect, Kay Brown, Mrs. Lewis, Harrison Lewis, Stella O'Connor, Monique Labranche, Hazel Clark; (*middle row*) Mary Maloney, Teresa Rousseau, Gerry Lemay, Ida Marcovitch, Jan Morin, Sars Hennessy, Pat Gosson, Lorne Cox, Munro MacLennan, Edith Wright, Pearl McGahey, Jean-Paul Cuerrier, Cora Honeywell; (*back row*) Hugh Schultz, Fred Ross, Dorothy Burns, Bill Taylor, John Tener, Cliff Ward, Bob Harris, Tom Hastings, Charlie Cardinal, Harold Currie (Photo credit: V. Solman).

season. Ian McTaggart-Cowan played an important role, not only as a mentor of wildlife biologists at the University of British Columbia but also by his contracted fieldwork on big game animals in western national parks. In central Canada, Wesley H. Curran of Queen's University conducted a biological investigation into the status and influence of Coyotes in Point Pelee National Park.

On 1 April 1949, Newfoundland and Labrador joined the Canadian Confederation. The eventual challenges inherent in introducing the Migratory Birds Convention Act to a population for whom the harvesting of country food was a long-standing tradition will be dealt with in Chapter 2. Initially, however, at least from the perspective of the Wildlife Service, the constitutional transition entailed little more than a courtesy visit by Harrison Lewis to Captain Harry W. Walters, then head of the provincial wildlife service, and to the new Premier, Joseph R. Smallwood. Smallwood assured Lewis of his whole-hearted support of federal efforts to conserve Newfoundland's avian resources.

"It will have my support," exclaimed the only living Father of Confederation. "In fact, I'm willing to be defeated on it."

Lewis, not easily carried away by rhetoric, remarked dryly in his notes, "No other politician ever said anything like that to me."[7]

On the same trip, Lewis met, interviewed, and hired Leslie (Les) M. Tuck as the first Dominion Wildlife Officer for Newfoundland and Labrador.

In 1950, the Department of Mines and Resources underwent another restructuring, the outcome being two new departments — Mines and Technical Surveys, and Resources and Development. The National Parks Service became the National Parks Branch within the latter department. The Wildlife Service now became a division of the Parks Branch, coequal with the Parks and Historic Sites Division and the National Museum of Canada. The duties and structure of the wildlife group continued essentially unchanged.

One symbolically important administrative alteration did occur at this time, though. On 6 April 1950, acting on a suggestion of George Stirrett, Harrison Lewis wrote to his Director, R. A. Gibson, suggesting that the Wildlife Division be authorized to use the title "Canadian Wildlife Service." The suggestion was approved, and, without fanfare, the name that would one day be legendary became official.[8]

Meanwhile, in an equally unassuming way, Lewis kept adding more members to the team. In Quebec, former summer student Louis Lemieux became Dominion Wildlife Officer, while H. R. Webster joined Joe Boyer in the Atlantic Region. By the end of 1951, the service employed 21 full-time biologists across Canada, as well as appropriate technicians, administrative staff, and student assistants.

Their work extended, literally, from sea to sea to sea. In Newfoundland, Les Tuck had begun the work on Thick-billed Murres that would ultimately lead to the inclusion of an extensive seabird research program among the ornithological priorities of the service (see Chapter 3). In the Maritimes, Joe Boyer was investigating the merganser population of the Miramichi watershed. Chief Biologist Vic Solman was overseeing studies of American Woodcock and Wilson's Snipe in Ontario and Quebec. In the west, Bill Fuller was conducting surveys of Bison, furbearing mammals, and Caribou. Far to the north, John Tener was investigating the Muskox of Ellesmere Island, John Kelsall was studying Barren-ground Caribou, and Dewey Soper was surveying waterfowl along the coast of the Beaufort Sea. And these were but a few of the activities of a few of the CWS biologists of the time.

Indeed, it was normal procedure to be engaged in a number of individual projects and studies simultaneously, as well as participating in national events such as the annual waterfowl breeding ground survey. In addition, employees were expected to cooperate with provincial and territorial game agencies and private organizations in activities ranging from the enforcement of migratory bird regulations to the promotion of wildlife conservation to community groups and schools.

Harrison Lewis is often recalled as a somewhat stern and forbidding chief, but there is no mistaking the enthusiasm and affection in his summary description of his team:

> I must say that I took a great deal of pride and delight in the young men of the Dominion Wildlife Service who were going into the vast expanses of northern Canada with prospects and opportunities before them such as have seldom been equalled. With plenty of elbow-room, they were not hemmed in by any office routine. They were well trained for their chosen work and were supplied with the funds, equipment, and co-operation necessary to do it. And they were placed in a land where the ecology was but sketchily known, where opportunities for adding to useful knowledge surrounded them on every hand.
>
> They did excellent work and served Canada well, and they were happy in doing so. A man works best when his work makes him happy. These young scientists not only enjoyed doing the tasks that had been set before them but had the ultimate satisfaction of demonstrating that they were equal to them.[9]

In March 1952, having nurtured the Wildlife Service through its first five years, Harrison Lewis retired. In four and a half years as head of the agency, he had identified and defined many of the themes that would preoccupy his successors for the next 45 years. His own terse note on the occasion reveals a lot about his character:

> I ought to say that my resignation was not requested nor was it the result of any serious difference or antagonism between my superiors and myself. It was simply based on my views as to how I should use such abilities and period of life as were my lot. I certainly did not intend that my life after retirement should be devoted to holidaying and loafing.[10]

Subsequent events would demonstrate how well he transmitted this view of public service to the biologists and research scientists who would follow in his footsteps.

Notes

1. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), page 263.
2. Anonymous, *History of the Canadian Wildlife Service* (Sackville, New Brunswick: Canadian Wildlife Service Library File, 1958; unpublished, unsigned manuscript attributed to J. Munro McLennan).
3. Lewis, *Lively*, page 265. (See note 1)
4. Lewis, *Lively*, page 266. (See note 1)
5. A. W. F. Banfield, *The Barren-ground Caribou* (Ottawa: Department of Resources and Development, 1951).
6. Lewis, *Lively*, pages 264–265. (See note 1)
7. Lewis, *Lively*, page 291. (See note 1)
8. Lewis, *Lively*, page 299. (See note 1) Lewis cites an amendment to Order-in-Council P.C. 3/330, 20 January 1950, as the authority for this change.
9. Lewis, *Lively*, page 273. (See note 1)
10. Lewis, *Lively*, page 32. (See note 1)

CHAPTER 2. Enforcing the Migratory Birds Convention Act

The death of the last Passenger Pigeon on earth, in a zoo in Cincinnati, Ohio, on 1 September 1914, probably triggered more general, public concern across North America for the welfare of migratory birds than did the sacrifice of millions of its forebears to the guns and snares of market hunters. Powerful though this symbol of extinction was, however, the political context that enabled it to be recognized had been carefully prepared beforehand. For years, on both sides of the border, advocates of conservation, such as John Macoun, John Muir, Charles G. D. Roberts, Ernest Thompson Seton, and Jack Miner, had worked to replace the frontier myth of wildlife as a limitless resource with a more realistic perception of it as a finite resource to be cherished. As spokesmen for an unofficial, but influential, coalition of hunters, naturalists, writers, and scientists who shared a common belief in the importance of conservation, they succeeded in arousing public opinion to a degree that commanded the respect of political leaders in Canada and the United States.

The signing of the Migratory Birds Convention at the end of 1916 marked a major victory in their campaign to win meaningful protection for wildlife. The subsequent passage of the Migratory Birds Convention Act (1917) in Canada and the Migratory Bird Treaty Act (1918) in the United States established the legal framework under which the two parties to the Convention would carry out their obligations.

The two Acts defined the groups of birds to be protected — waterfowl, cranes, rails, shorebirds, doves, insect-eating passerines, and seabirds — and outlined the regulatory and control measures that the authorities of the day envisaged as necessary. In a revealing omission, they excluded raptors and corvids, reflecting a widely held view that predatory birds such as hawks, crows, and assorted fish-eating birds were natural foes of conservation and should be eliminated.

In Canada, the Act not only confirmed the identity of the protected families of birds but enumerated the types of regulation that the minister responsible might impose on their behalf. These included the establishment of closed seasons and bag limits; the granting or withholding of permits for hunting migratory birds, for aviculture, and for collecting birds, eggs, and nests; and the establishment of protected areas and sanctuaries. The Act prohibited the unregulated sale, purchase, or possession of birds, nests, or eggs. It allowed for the appointment of game officers, delineated their powers, and specified offences under the Act and the range of penalties that might be imposed on convicted offenders.[1]

Regulations made pursuant to the Act defined hunting seasons and bag limits, outlined prohibitions, and generally converted the broad intentions of the Convention into practical, enforceable rules. Where appropriate, they also stated exceptions to the rules, notably with regard to aboriginal hunting rights, protection of agricultural crops against the depredations of birds, and the conditions under which special possession permits might be issued to aviculturists, taxidermists, and scientific researchers.

Experience would show the Canadian public to be generally sympathetic to the intent of these legal steps and compliant with the rules and regulations. Naturally, there would be exceptions. The notion that every citizen had an inalienable right to harvest wildlife at will was deeply rooted in the pioneering traditions of North America. However, the memoirs of early Wildlife Officers such as Harrison Lewis[2] and Robie Tufts,[3] as well as the personal recollections of their successors, suggest that few of the lawbreakers were hardened criminals. In most parts of Canada, the typical poacher, whether local citizen or visiting sportsman, seems to have been motivated more by ignorance, self-indulgence, and greed than by a malicious desire to profit from a life of crime.[4]

This is not to deny that there were violations of the Migratory Birds Regulations. After passage of the Act, a recalcitrant minority of hunters continued to bait blinds, ignore bag limits, and shoot out of season. Some do so still. Furthermore, much of the constituency that supported the passage of the Migratory Birds Convention Act might fairly be characterized as urban, educated, and affluent. In isolated areas such as Quebec's Lower North Shore and the more remote coastal communities of the Maritimes, spring seaduck hunting and the harvesting of eggs from seabird colonies were deeply rooted traditions, sanctified by centuries of living off the bounty of land and sea. Many residents of Canada's far north depended even more heavily on country foods of all sorts, including birds, for their subsistence.

However, it was not in Canada as constituted in 1917 that the federal authority to protect migratory birds met one of its greatest tests. That challenge began in 1949, with the entry of Newfoundland into Confederation, and continued for nearly half a century before it was resolved.

The Confederation Challenge

To a degree unknown in settled, southern Canada at the time, residents of Newfoundland's outports depended on fish and game for sustenance. In winter, as the pack ice moved southward, cutting off many settlements from contact with the outside world, seabirds were often their only source of fresh meat for months at a time. Understandably, inhabitants of these communities were distressed to learn that their newly acquired Canadian citizenship made them subject to the Migratory Birds Convention Act and Regulations.

The first indication that most rural Newfoundlanders had of this change in their ancestral ways came in the fall of 1949. On 1 October, the *Twillingate Sun* published a vigorous editorial protest:

> Never in the history of Britain's eldest colony and Canada's latest province has a man-made law hit one particular section of its population such a staggering blow. When it is further realized that this amazing piece of legislation is sprung upon them without warning and without explanation those concerned cannot be blamed for feeling badly used.
>
> No subscriber of ours...will wonder what we are talking about. By this time the news has spread like wildfire — you can't kill a turr [murre] or a bullbird [dovekie] this year and unless the law is repealed that condition will apply throughout your lifetime and that of your children and your children's children....There is no excuse for the government's failure to have the contents of this important piece of legislation published or broadcast....Had not some person gone to the Ranger Office to get a Bird License and been given with the license a summary of the regulations, not one in every thousand would have known about it.[5]

The controversy grew swiftly, but it was not until 5 November that the press reported the federal government's response to the uproar:

> Mr. Leslie M. Tuck, a Newfoundland teacher who became a well-known ornithologist, has been appointed Dominion Wild Life Officer for the Province of Newfoundland. The job...is to watch over clauses of the Migratory Birds Convention Act in Newfoundland and Labrador and see that they are kept....To Mr. Tuck it should be comparatively easy. Ever since he enrolled at Harvard in 1936 as a special student in Natural History, ornithology has been his hobby and his life.[6]

Les Tuck was an excellent choice. A native of Shoal Harbour, Trinity Bay, Newfoundland, he was a well-known and respected naturalist. He had already added more than 30 species to the Newfoundland list of birds and had published widely in ornithological journals. Now, he was faced with a challenge of an entirely different sort: to gather information on the status of murres in Newfoundland and to integrate a new and unfamiliar conservation ethic into the value system of a society that felt no particular need for it.

Within a week, Tuck had penned and circulated this politically sensitive news release:

> It is recognized, that many people around the coasts of Newfoundland are accustomed to depend on the meat of the Murre, or Turr as it is locally called, for food, and have made no substitute provision for the winter. Hardship might be experienced by these families if those birds could not be obtained. While the Convention does not provide an open season for the Turr, since it is not one of the game birds, the authorities do not for the present propose to interfere with residents of Newfoundland who, because of need, take and possess Turrs for their own use and that of their families. This does not, however, apply to bullbirds [dovekies], tickleaces [kittiwakes], noddies [fulmars], or bawks [shearwaters] which the Treaty protects throughout the year.[7]

The winter of 1949–1950 passed without confrontation. The following year, however, steps were taken to execute a progressive application of the law. A ban on turr hunting would start along the south coast in the first year and gradually shift northward to cover the whole province.

Meanwhile, despite his 1949 assurance to Harrison Lewis that he would be prepared to go down to defeat on the issue of migratory bird protection (see Chapter 1), Premier Joseph Smallwood was carefully disengaging himself from responsibility for the issue. Less than two years later, he was telling residents of the south coast that if they were prevented from hunting, it would be the federal government's doing and hopelessly beyond his power to remedy.[8]

Within weeks, the public outcry had moved the Honourable Robert Winters, Minister of Resources and Development, and the Honourable Lester B. Pearson, Minister of External Affairs, to promise that they would take up with Washington the matter of an exception to the Migratory Birds Convention.[9] To bolster the resolve of the federal ministers, the provincial House of Assembly gave unanimous support, on 17 April 1951, to a resolution put forward by Harold Horwood, writer and Liberal Member of the House of Assembly for Labrador, requesting the Government of Canada to relax the prohibition against the killing of seabirds for food by Newfoundlanders.[10]

A month later came the eagerly awaited news that, pending completion of further study into the biology of the species, regulations against turr hunting would not be enforced in Newfoundland.[11]

For the next two years, little was heard on the subject of turr hunting. Tuck continued his research, the baymen continued to shoot turrs, and the police continued to turn a blind eye to the infractions as long as they were neither too obvious in nature nor too commercial in intent. In 1956, this view gained a degree of official sanction with the passage of a federal Order-in-Council allowing "needy" rural residents of Newfoundland to hunt murres for food, but extending the ban on selling and the prohibition against killing other species of seabirds. This de facto solution continued in force for the next 16 years. Then, in 1972, the regulations under the Migratory Birds Convention Act were formally amended to read:

> In the Province of Newfoundland, a resident of the Province may, without a permit and during the period commencing on September 1st and ending on March 31st, hunt murres for human food only.

In one sense, the regulation was little more than an acknowledgment of the status quo. On the other hand, it achieved two important goals. By allowing a nominally regulated hunt for one plentiful species, it won general acknowledgment that other seabirds were not to be touched. It also established a clear-cut distinction between a traditional harvest of country food and the practice of market hunting: one was permissible, but not the other. That distinction would be of crucial importance when the issue next surfaced, some 15 years later.

In retrospect, the entire episode demonstrated an inherent civility in what might otherwise have become a bitter and ugly dispute. From the outset, hunters, journalists, politicians, and the Wildlife Service all subscribed to the proposition that it was wrong for any wildlife species to be put at risk by excessive hunting. Political passions were focused on the question of whether outright prohibition was an appropriate solution and whether a people who had not been party to the original negotiation of the Migratory Birds Convention could fairly be bound by its provisions. Viewed strictly in relation to the Convention itself, the 1972 regulation was an expedient measure without legal validity. The problem of seabird hunting would surface again, but in the short term the regulation represented an acceptable working compromise for all parties.

Building an Enforcement Team

Meanwhile, CWS was transforming its role in the administration of the Migratory Birds Convention Act on a national scale. Since October 1932, when an Order-in-Council had assigned the task of enforcing the federal Migratory Game Bird Regulations to the RCMP, the Dominion Wildlife Officers had been essentially relieved of their policing responsibilities (see Chapter 1). The effectiveness of the arrangement varied. In areas where Mounted Police officers attached a high priority to conservation, their commitment was evident in close supervision and strict enforcement. Where their interest was low, the commitment to enforcement and prosecution was less rigorous. By their own admission:

> ...enforcement of the Act and Regulations was sporadic, with little consideration given to maintaining a consistent enforcement effort throughout Canada. Conditions would be allowed to deteriorate to the point at which complaints were received, and additional patrols would then be laid on to control the immediate situation.[12]

This disposition of the enforcement responsibility remained in effect without significant change through the 1930s and 1940s and, indeed, continued for the first 15 years after the creation of CWS. In all fairness, part of the unevenness of the approach also stemmed from the fact that some provinces had their own game laws that closely paralleled the federal regulations, as well as their own game officers to enforce them. Where these circumstances prevailed, the RCMP saw no practical purpose in duplicating the provincial effort.[13]

Nevertheless, by the late 1950s, CWS Chief William Winston (Bill) Mair and Chief Ornithologist David Munro were sufficiently concerned about the inconsistency of enforcement that they requested departmental intervention to have the federal police force live up to its responsibilities.[14] Eventually, the request resulted in action. Superintendent A. Huget, Officer in Charge of the Criminal Investigation Branch, "G" Division, explained the consequences some years later, in a presentation to the Federal–Provincial Wildlife Conference of 1967:

> A step of major significance was taken in 1960 when the Deputy Minister of Northern Affairs and National Resources reviewed the role of the Force in enforcement of this federal statute vis-à-vis the Canadian Wildlife Service. Two alternatives were suggested at that time: *first*, to create within the R.C.M.P. a group of members who would devote their full time to this work, or *second*, to incorporate such a group within the Canadian Wildlife Service.
>
> After a series of discussions at that time, the R.C.M.P. agreed to the suggested concept of creating a special group within the Force and thus the Migratory Birds Convention Act Special Enforcement Group was born.[15]

Regardless of good intentions, the special enforcement group was slow in starting. In 1961–1962, the manpower commitment of the RCMP to this undertaking was limited to the appointment of a national coordinator in Ottawa and a single field officer in the Province of Quebec. The following year, a field complement of five constables was approved, and by 1966, the special squad had 10 members across the country. Members of this group were chosen on the basis of declared personal interest. Their mandate included active promotion within their respective divisions of the Migratory Birds Convention Act and Regulations and close liaison with CWS personnel to identify areas where infractions were frequent.[16]

The task was challenging, not only because the responsible officers were spread thinly across a

Shared responsibilities under the Migratory Birds Convention Act encouraged a close working relationship between CWS and the RCMP. Here, David Munro (*2nd from left*) and CWS Chief W. W. (Bill) Mair discuss enforcement matters with two members of the force (Photo credit: CWS).

vast territory, but also because many of their colleagues in the force ranked the concerns of the "bird and bunny patrol" far below "real" crimes like murder or robbery.[17] Despite such attitudes on the part of their colleagues, many members of the special enforcement group were dedicated and effective officers. James A. (Jim) Stoner, a member of the RCMP special squad for the Maritimes at the time, was one who welcomed the challenge. Faced with a local populace that clung tenaciously to the regional tradition of a spring hunt for seaducks, he found helicopter surveillance to be a useful tactic for capturing poachers. The work could be dangerous:

> The area around Cape Sable Island had long been a centre for illegal hunting, so one year I organized a fairly large operation to try and deter it. We had Mounted Police officers stationed along the shore to intercept any hunters that attempted to escape and a patrol boat offshore, just beyond the horizon, to round them up if they took off for open water. I was in a helicopter, circling above several boatloads of hunters, when the operation came to an abrupt halt.
>
> I had been leaning out the door of the helicopter to take pictures and direct the hunters to go ashore when we went into a sudden counter-torque turn. My first thought was "What the hell's the pilot doing?" When we did a second turn, I realized he'd lost control and when he didn't pick it up the third time I knew we were going to hit the water. As it happened, we went in upside down. It was a Bell 47G2 with a cockpit like a fishbowl. The top disintegrated and as the water came swirling around inside I thought "Just like being in a Bendix washer!" I managed to get out and reaching the surface I waved one of the boats over. Just then the pilot surfaced as well. When the helicopter was towed in they found that the blade had sliced through the cockpit right between the pilot and me. I never enjoyed flying a helicopter quite as much after that.[18]

Important though the accomplishments of the special squad were, CWS management felt the need for enforcement was not being met adequately. In 1966, Ron Mackay and William R. (Bill) Miller were appointed as Regional Supervisors of Surveys and Enforcement for the Western and Eastern regions, respectively.[19] That same year, two enforcement coordinators were named to field positions: J. A. (Andy) Poitras in the Maritimes and J. A. (Joe) St. Pierre in Quebec. In 1967, J. C. (Jack) Shaver was appointed as coordinator for the Western Region.

Bill Miller was a biologist who believed strongly in the importance of enforcement as a wildlife management tool. As Chief of Surveys and Enforcement, he displayed an immediate interest in improving the quality of the work, pressing the RCMP for more patrols and more prosecutions. He had a reputation for bluntness. On one occasion, he reportedly confronted an RCMP divisional commander with the demand: "Haven't you got anyone who knows something more than the Musical Ride?"[20] Blunt he might be; he was also persistent and persuasive. At the same conference addressed by Superintendent Huget, Miller expressed a somewhat more rigorous analysis than that of the RCMP officer:

> As has been pointed out in criticism in the past, it is unsatisfactory that our problem periods always seem to coincide with priority criminal outbreak, i.e. murder, rape, and safe-cracking! We even lose special squad service to guard duty priorities when political personages arrive on the scene. If my information is correct there has to date been a 100 per cent turnover of special squad members since its inception in 1961. Too often the

Poachers of migratory game birds keep a sharp eye out for the law, but sometimes to no avail. Members of an enforcement strike team in the early 1970s display guns and birds seized during a raid on an illegal spring hunt (Photo credit: CWS).

present constable member is met with apathy and in some instances ridicule at the task ahead of him, that of selling the need for better wildlife law enforcement.[21]

To address this problem, Miller called for the RCMP to assign a minimum of two officers per province to wildlife enforcement work, "with the allocation of additional men depending on the need during seasonal problem periods."[22] He acknowledged that:

A central problem in making this cooperative effort at enforcement work is to indoctrinate biologists with enforcement principles and methods and to give police officers a broader biological background. A definite meeting of minds is necessary.[23]

This could be accomplished by reciprocal training and by creation of a "nucleus law enforcement group" within CWS. This unit, which he proposed should consist of 20 to 25 members, would promote closer liaison between the Wildlife Service, the RCMP, and provincial wildlife agencies, conduct surveys related to hunting, and participate directly in special operations aimed at the arrest and prosecution of offenders.

While Bill Miller's vision of a coordinated, mobile strike force was never fully realized, the number of CWS enforcement officers was augmented significantly over the next several years. Jim Stoner transferred from the RCMP to take up an enforcement coordinator's job in Ontario in 1969. After the reorganization of CWS field operations into five regions in 1975, the number of enforcement officers increased significantly across the country. Gary Dick covered the Pacific and Yukon Region under the coordination of Ron Mackay. Jack Shaver headed up enforcement in the Western and Northern Region, where he was joined by Chuck Gordon in Alberta, Gary Bogdan in Saskatchewan, Eugene Whitney in Manitoba, and Glen Williams in the Northwest Territories. In 1996, W. David (Dave) Paul published *Confessions of a Duck Cop*, a lively collection of anecdotes about the dedicated struggles of CWS enforcement officers to protect Canada's migratory game birds against the depredations of poachers, vandals, and wildlife traders.[24]

A large part of their work was preventive, focused on liaison and motivational work with RCMP and provincial game officers. Dozens of workshops were held to train police and game wardens how to identify birds in the hand and on the wing and to explain why some species were protected more strictly than others. The coordinators' job did not stop at education, however. They had to initiate police work as well, in order to demonstrate a meaningful presence and maintain credibility with other enforcement agencies. When migratory game bird officers got together, they were never short of tales to tell about poachers and other malefactors. One of Jack Shaver's favourites involved the attempt of a local politician to intimidate him:

Many dedicated conservation officers helped make the enforcement arm of the Wildlife Service an effective force for the protection of migratory game birds across Canada. If one individual could be selected to embody their determination, it would probably be W. R. (Bill) Miller, seen here on patrol in the camouflage hunting gear that he preferred to a formal uniform (Photo credit: CWS).

One day I picked up this chap who was Mayor of a large town in Alberta. He had about 12 or 15 geese with him, in an area that was posted for no hunting. Well, he got really mad, and to impress me he told how I'd never see him in court because he was a great friend of the Premier. So I said, "You'd better just take a closer look at my badge, mister, because I'm a federal officer. Now, how well do you know the Prime Minister?" And he did go to court. And he lost his migratory bird hunting privileges for a year for that offence.[25]

Cooperation and teamwork were the essential watchwords of an enforcement effort that achieved improvements out of all proportion to the human and financial resources that were available. In an overview such as that afforded by the present text, it would be impossible to describe in full detail the spirit and dedication of the enforcement officers in the field. Indeed, despite a cast of colourful characters and a narrative packed with outdoor adventures, it is entirely possible that the full contribution of the CWS enforcement team may never be adequately chronicled. Enforcement officers of the "old guard" retain a strong *esprit de corps* even in retirement. Although they possess a rich oral tradition of anecdotes, their stories tend to be told most freely not for the record but when a few old companions in arms get together to reminisce among themselves.

Science and Enforcement

Knowledge was yet another critically important element of enforcement and one where the sometimes disparate scientific and enforcement strengths of CWS could come together in a productive partnership. In 1966, coincident with the announcement of a National Wildlife Policy (see Chapter 10), a mandatory Canada Migratory Game Bird Hunting Permit was introduced. This step, initiated in 1966 under the guidance of Denis A. Benson, enabled CWS to initiate two important surveys. One, the National Harvest Survey, was conducted through a questionnaire sent to selected permit holders and produced information on hunting activity and the demographic characteristics of the hunting population. The other, the Species Composition Survey, started in 1967. It was based on a sampling of wings and tails returned by permit holders and furnished data on the age, sex, and species composition of the annual kill. The statistical design of the harvest survey was at the leading edge of questionnaire-based research. Developed by Amode Sen, then head of the CWS Biometrics Division, it represented an important contribution to research methodology.[26]

As the world entered the computer age, the tools for analyzing harvest and population survey data became increasingly rapid and sophisticated. J. Stephen (Steve) Wendt, who joined CWS in 1976, played a key role in helping CWS to adopt and adapt the new information technology to the needs of conservation and enforcement. Switching from manual to automated sorting streamlined the formerly tedious task of processing half a million migratory bird hunting permits every year. Other changes that Wendt initiated included a system for input, storage, and retrieval of bird banding data and permit records and an original technique for extracting data in relation to particular geographic areas.

Analysis of National Harvest Survey and Species Composition Survey data could produce a wide variety of information, ranging from the theoretical to the practical. Much was primarily relevant to the setting of hunting regulations for each coming year. Some had a direct application to enforcement activities in the field. A good example of this was the geographical analysis of waterfowl kill on the basis of which maps could be generated to indicate the estimated harvest of birds per unit of area in districts that were subjected to intensive hunting.[27] It was one of these maps that Bill Miller and Jim Stoner brought with them on a trip to North Bay, Ontario, where they hoped to stimulate the local RCMP detachment to make a somewhat more energetic enforcement effort. Stoner would later recall:

> We called the RCMP detachment ahead of time to let them know we were coming. They said,"Why? There's nothing going on here." Well we got up there and checked into our motel, looking just like a couple of hunters. Bill had his dog with him and pretty soon this guy came up and asked if we were going hunting. He told about some good places to go and about all the illegal hunting that went on in that location. We went out there the next day and we ended up prosecuting various people for violations. It sure opened up the eyes of the detachment, especially when we showed them how maps from the surveys helped guide us as to where we should look for hunters....But the point we were really making to them was this: if you don't go out looking, how the hell do you know what's going on?[28]

Annual wing bees across Canada generated valuable information on the species composition of waterfowl harvests. Participants in this one, held at Sackville, New Brunswick, in the early 1970s, included Jim Collins and Keith McAloney (*centre*) and Al Smith (*upper right corner*) (Photo credit: CWS).

In 1973, Stoner became even more deeply involved in the business of finding out what was going on when he accepted a move to headquarters to work more closely on surveys and enforcement with Graham Cooch, then Chief of the Populations and Surveys Division. The position carried with it responsibility for the development, formulation, and coordination of a national enforcement policy and program. Within a year, the task of developing and enforcing annual regulations was transferred to a newly created Regulations and Enforcement Division, with Stoner at its head.

Armed with a philosophical certainty that wildlife law enforcement was the cornerstone of any effective wildlife management program, Stoner welcomed the opportunity to lead this initiative. His police background gave him credibility among the field officers. His appreciation of the importance of scientific methods of data collection and analysis enabled him to work closely with ornithologists like Cooch and Hugh James Boyd, then Director of the Migratory Birds Branch.

The issuance of regulations under the Migratory Birds Convention Act is a function of the Minister. In practice, however, the determination of what changes in the rules and restrictions best serve the interests of migratory game bird management results from discussions between federal and provincial scientific and enforcement authorities in Canada, in consultation with their counterparts in the United States. For many years after the Act came into force, this process took place at the Federal–Provincial Wildlife Conference. There, the delegates would review information on the past year's hunt and the current year's prospects for game bird production and make their recommendations to the Minister. As the quantity and sophistication of survey data increased, it became impractical to deal with the topic in a single roundtable session. As Chief of Regulations and Enforcement, Stoner, assisted by Réjean (Ray) Lalonde, coordinated information from regional technical committees, consulted with Graham Cooch and Hugh Boyd, and drafted recommendations for review by regional directors and the Director General.

During the mid-1970s, a variety of wildlife-related issues other than routine updates of the regulations required thoughtful, constructive input from a law enforcement perspective. Stoner found himself advising on aspects of the new Canada Wildlife Act and other environmental legislation. He was also an active participant in tripartite discussions with provincial and First Nations' representatives to develop the portion of the James Bay Agreement dealing with native hunting rights.

In order to achieve a higher profile for the role of enforcement, he argued successfully for devoting the agenda of the 1977 Federal–Provincial Wildlife Conference to the theme of "Wildlife Enforcement in Canada." Papers presented on that occasion ran the gamut of viewpoints. The keynote address, by Robert H. Scammell, an Alberta lawyer and outdoorsman, called for common sense in the setting of regulations and — an echo of Bill Miller's comments of a decade earlier — the appointment of "a few elite, properly trained squads of hard-nosed, owl-eyed enforcers to hammer the poachers in a given area...and thus educate every poacher everywhere."[29] A contrary point of view was expressed by A. S. Murray, Associate Deputy Minister (Operational Policy and Engineering Services) in the Manitoba Department of Renewable Resources and Transportation, who offered a foreshadowing of challenges to come when he stated:

> We as managers aren't really certain what enforcement costs. What we do know [is that] these costs are likely to be high in relation to the benefit received....
>
> ....Perhaps we should just show the flag and concentrate our energies elsewhere.[30]

With the animated discussions that followed these and the dozen or more other papers presented, it is doubtful whether the topic of wildlife law enforcement in Canada ever received a more thorough examination in a more knowledgeable forum.

Public education has traditionally been an important way of carrying out the CWS game enforcement mandate. Information booths, such as this one at the 1991 Vancouver Sportsmen's Show, provide an opportunity for officers like Garry Grigg (*l.*) and Colin Copland (*r.*) to promote awareness of the need for conservation and law enforcement (Photo credit: G. Grigg).

Throughout the 1980s, the enforcement coordinators met annually to review regulations, policies, and programs. Owing in large measure to severe financial cuts, a certain degree of tension was perceptible between the scientific and enforcement arms of the Wildlife Service during this period. The gulf that Bill Miller had identified in the mid-1960s between some biologists and some enforcement officers had narrowed very little 20 years later. In a climate of budgetary restraint, members of the CWS enforcement group felt isolated from the mainstream of policy and planning and deprived of resources they needed to do the job as they saw fit.

How they saw the job was an important factor. Most of the enforcement chiefs and coordinators of the period had begun their careers as police officers, many of them with several years of experience with the RCMP before they joined CWS. They frequently tended to be rugged individualists with a strict sense of right and wrong and a dubious opinion of anyone whom they judged to be soft on crime. In contrast, the new generation of Regional Directors was faced with a pressing need to build a broader base of public support for CWS in order to avert the fiscal starvation of the agency. Their preferred strategy was to emphasize public education in conservation values as a primary tactic for integrating compliance with the regulations into the wildlife management process.

An anecdote by CWS biologist Richard D. Elliot illustrates the tension between the two approaches:

> I remember touring the south coast of Newfoundland in the mid-1980s with a provincial game officer. At one wharf we encountered a man who had just come in with about 25 turrs. Among the birds I also noticed one guillemot. I knew the game officer was of the old school, a "by the book" kind of guy. If he had seen that bird, he'd have insisted on laying a charge, word would have got round the bay, and I'd have lost the confidence of every hunter in the neighbourhood before I ever won it. Shielding the guillemot from view with my boot, I turned and thanked the officer for the introduction. Then, while he went on his way to attend to other duties I took advantage of the opportunity to explain to the hunter why all seabirds with the exception of turrs were protected. From there we turned to the topic of illegal hunting and regulations and I believe I made far more mileage in terms of winning hunter compliance by turning a blind eye on that occasion than would ever have been accomplished by a confrontation.[31]

Emerging Issues — Newfoundland

The thorny issue of the turr hunt had resurfaced in Newfoundland thanks to a combination of social and technological factors. During the 1960s, the government of Premier Smallwood had initiated a massive economic development scheme under which residents of hundreds of isolated outport communities were relocated to designated urban growth centres. Along with their heirlooms and their memories, they brought with them an abiding taste for the rich, dark flavour of turr. To satisfy their cravings, market hunters began shooting turrs by the truckload to sell from door to door along the streets of St. John's, Mount Pearl, Grand Falls, and Corner Brook.

In pre-Confederation days, when a hunter had to row his dory over the icy North Atlantic swells, commercial hunting on this scale would have been impractical. In the 1980s, under favourable conditions, two or three hunters with semiautomatic shotguns and a fibreglass speedboat with powerful inboard/outboard engines could kill hundreds of turrs in an afternoon. At tailgate prices of $2 to $5 per bird, the temptation to earn easy, tax-free cash was too great for some to resist.

In the 1950s, Les Tuck had estimated the annual harvest at 100 000 to 200 000 birds.[32] Thirty years later, CWS biologists put the figure at 725 000 to 1 million.[33] As the resident CWS seabird specialist in St. John's, Richard Elliot found widespread agreement among hunters that as many as one-third of those birds might be sold. In his view, quite apart from the illegality of the trade, an annual harvest of this many birds was not sustainable. Armed with detailed evidence of trends in the wintering murre population, Elliot and CWS technician Pierre Ryan set out to enlist the moral support of the vast majority of hunters who favoured conservation of the birds.[34]

By 1991, George Finney, CWS Regional Director for Atlantic Canada, could state:

> The results reflect the common sense of most hunters and the commitment of our biologists to finding workable solutions. Over the past six or seven years, we've met with turr hunters in more than 175 communities to promote dialogue on this subject. At first, people were apprehensive....Now, we're being actively petitioned to do something constructive about the hunt.[35]

The following year, ice conditions around southeastern Newfoundland concentrated large flocks of the birds so densely that in some places the hunt resembled the proverbial shooting of fish in a barrel. At Finney's request, Director General David Brackett invoked an emergency regulation under the Migratory Birds Convention Act to close the season a month earlier than usual in Fortune Bay. In 1993, the season was cut short in Placentia and Fortune bays on similar grounds.[36]

This was, to say the least, an innovative use of the emergency powers granted to the Minister by Section 37 of the Migratory Bird Regulations. Those powers are, basically, to "vary any hunting period or quota set out in these Regulations" in the interest of conserving migratory game birds. Finney and Elliot had amply demonstrated that the unregulated situation of the murre hunt constituted an ongoing conservation emergency. Strictly speaking, however, the murre was not a migratory game bird, despite the existence of a de facto hunting season and the common intention of Canada and the United States to amend the Migratory Birds Convention. At the time, the success of the decision to apply the regulation to murres depended on how strong a pro-conservation consensus had been built with the Newfoundland hunting community.

Most hunters applauded the intervention. At the same time, it was recognized that a long-term solution was required. For the 1993–1994 season, therefore, the general regulation that permitted Newfoundland residents to shoot an unlimited number of turrs over a seven-month period was replaced by a schedule of specific local seasons correlated to the seasonal progression of the birds around the coast. Bag and possession limits were introduced for the first time, making it harder for market hunters to conceal their activities.

Adoption of a more proactive policy with regard to the hunt did carry an element of risk. Technically, the interim regulation governing the hunt was contrary to the Migratory Birds Convention, which did not recognize murres as game birds. An amendment to the Convention could be effected only with the consent of the signatory powers.

Emerging Issues — Aboriginal Hunting Rights

Had the question of the turr hunt been the only unresolved irregularity in the application of the Migratory Birds Convention, it is open to question whether Washington would have been willing to launch such an expensive and time-consuming endeavour. Fortunately, both nations had other concerns to bring to the table as well. Among them was the issue of hunting by aboriginal peoples.

As early as 1763, a Royal Proclamation of George III had extended protection to the "several Nations or Tribes of Indians" against their being "molested or disturbed in the Possession of...their Hunting Grounds." However, the legal concept of aboriginal rights had, if anything, diminished since that time. It appears to have been only a minor consideration when the Convention was drafted in 1916. As in Newfoundland, isolated communities in northern Canada and Alaska depended on migratory birds and their eggs as a seasonal food supply. Consequently, a major discrepancy between the letter of the law and its application among aboriginal peoples in the north was virtually inevitable.

During the 1960s, the disposition of a number of cases in which aboriginals were charged with offences under the Migratory Birds Convention Act illustrated the nature of the dilemma and underlined the urgent need for a constructive solution. In the case of *Sikyea v. The Queen* (1964), a ruling by the Northwest Territories Court of Appeal that aboriginals had an inherent right to hunt and fish for food on unoccupied Crown lands was overturned by the Supreme Court of Canada.[37]

Four years later, in 1968, another case (*Daniels v. The Queen*) offered evidence of how complex this issue could be. In this instance, an aboriginal named Paul Daniels had been charged with possession of migratory birds out of season. In his defence, it was argued that a specific agreement between the Government of Canada and the Government of Manitoba, dated 14 December 1929, gave aboriginal peoples the right to hunt game for food at all seasons on unoccupied Crown lands in that province. The Supreme Court of Canada ruled, in a 5–4 split decision, that Mr. Daniels must be found guilty because the Migratory Birds Convention Act prevailed over the federal–provincial agreement.[38]

Sound as this decision might be in law, it did little to accommodate the genuine needs of people who lived off the land all year. On 17 May 1968, just three weeks after the Supreme Court ruling in the Daniels case, CWS Director David Munro wrote to the RCMP and the provincial and territorial wildlife directors:

> I realize that the situation is most unsatisfactory as it still places enforcement officers in an awkward position. Nevertheless, I must ask that no charges be laid against Indians hunting for food on Indian Reserves or unoccupied Crown land unless there is clear evidence of waste of birds taken. If non-Indians are found hunting with Indians in contravention of the regulations, charges should be laid.[39]

The so-called "Munro doctrine" was implemented without delay. Within a month, Manitoba's Director of Wildlife had instructed his field staff that aboriginals were to be exempted from compliance with the Migratory Birds Convention Act. For the next several years, game officers and the RCMP turned a blind eye to infractions by native people engaged in hunting for food. In September 1975, however, an aboriginal in Manitoba, Larry Catagas, was charged with possession of six ducks killed out of season, in contravention of section 6 of the Act.[40] The accused did not deny having the ducks, but argued that the policy of nonprosecution invalidated the charge. On that basis, the trial judge acquitted him. However, the Crown appealed the acquittal, and in November 1977 the Manitoba Court of Appeal found the defendant guilty, issuing a stern criticism of the wildlife authorities who had, in the court's view, undertaken "to grant a dispensation in favour of a certain group, exempting them from obedience to a particular law to which all others continued to remain subject." Although they acknowledged that the intent of the exemption was "benevolent," the appeal judges found that the power of the Crown to dispense with any law without parliamentary approval had been ended in 1688 with the enactment of the Bill of Rights by the English Parliament.

Still, the fundamental issue of aboriginal hunting rights remained unresolved, although in 1979 a serious but unsuccessful attempt was made by both Canada and the United States to amend the Convention (see Chapter 10). Passage of the Constitution Act of 1982 added urgency to the question. Section 35 of the new Canadian legislation included explicit guarantees of those traditional hunting rights that the Migratory Birds Convention had failed to recognize. Prior to 1982, the courts had insisted that federal laws must prevail over aboriginal rights. Now, with those rights enshrined in federal law, decisions started going the other way. In the landmark *Sparrow* case, the Supreme Court ruled that the defendant had been exercising a constitutionally protected aboriginal right to fish for food in the traditional fishing waters of his Nation, and that the existence of regulations under another Act did not extinguish that right.[41] Subsequently, the Department of Justice advised that closed season provisions of the Migratory Birds Convention Act might no longer withstand Supreme Court scrutiny when applied to people who possess aboriginal or treaty rights.[42]

Meanwhile, the James Bay and Northern Quebec Agreement and a growing number of other aboriginal land claims settlements in both Canada and the United States were further emphasizing the dissonance between the Migratory Birds Convention and the practical challenges of wildlife management and protection in northern areas. Thus, while the Wildlife Service continued to promote vigorous enforcement and public education, international diplomacy became a third strategic priority. From 1990 to 1995, a painstaking process of consultation took place between a wide variety of Canadian and American government agencies. Aboriginal groups and non-government environmental advocacy organizations also contributed to the dialogue.

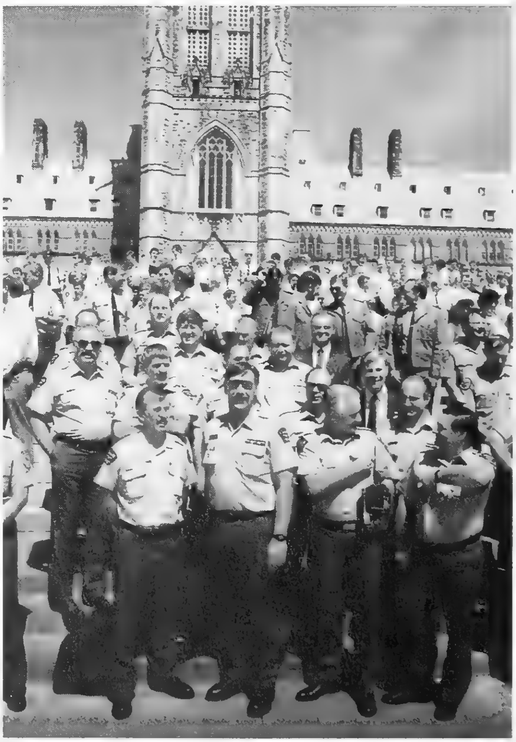
Adjusting to a Changing World

Motivated in part by these developments, CWS turned in the 1990s to revisit the whole topic of regulation. In 1989, Steve Wendt became Chief, Migratory Birds Conservation. He assigned biologist Kathy Dickson the task of developing status reports and regulatory reports for waterfowl. The public information and consultation documents that she designed remain in use almost a decade later, and she was a key participant, along with Anton M. (Tony) Scheuhammer and others, in a study of lead in waterfowl[43] that resulted in a nationwide ban on the use of lead shot by hunters.

In a broader initiative of the same period, the Wildlife Service undertook a general review of the federal Migratory Birds Regulations in 1993. This effort, led by Patricia (Pat) Logan, identified many discrepancies and opportunities for corrective action, either through new legislation or through revision of existing regulations.

A series of major adjustments to the work of enforcement officers had begun in 1985, when they were assigned responsibility for enforcing the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; see Chapter 10). In 1988 came a further change, as the RCMP dismantled its special migratory birds squad, leaving its duties to the discretion of local detachments, as in the 1960s. Regional waterfowl enforcement sections then had to pick up the slack. These two new pressures meant that, to a greater degree than ever, CWS officers had to take on a proactive policing role, which included an examination of the overall organization of enforcement work across CWS.

When Yvan Lafleur succeeded Jim Stoner in 1989 as Chief of Enforcement at CWS headquarters, he received a mandate to review the overall structure and organization of enforcement activities and, with the support of Ray Lalonde, André Chartrand, and



In July 1993, more than 400 delegates from 50 North American jurisdictions met in Ottawa to discuss cooperation in wildlife protection and enforcement. CWS game officers and officials in attendance included: (*front row, l. to r.*) Wayne Spencer, Gary Dick, Guy Lafranchise, André Boudreau, Yvan Lafleur; (*middle row*) Gene Whitney, Ray Lalonde, Garry Bogdan, Al Giesch, Dave Brackett; (*back row*) Jacques Chagnon [partially hidden], Ken Tucker, Wayne Turpin, Les Knoll, Randy Forsyth, Bob McLean (Photo credit: G. Grigg).

Robert (Bob) McLean, to determine the degree to which appropriate legislation was in place to support them. Policies and procedures were developed, and 10 new enforcement officers were added to CWS staff. By 1991, enforcement of CITES had assumed more importance, particularly in ports such as Vancouver, and officers were involved in international CITES projects. With enforcement within CWS more effectively coordinated, efforts to develop coordinating mechanisms with CWS's enforcement partners began, resulting in, for example, the formation of an association of enforcement chiefs from five federal agencies, the provinces, and the territories to develop common strategies and undertakings.

On the legislative front, several important steps were taken between 1989 and 1994. After many years of discussion, an entirely new piece of legislation, the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act, was drafted and passed in 1992 (see Chapter 10). Bob McLean, by then acting Chief of Program Planning and Coordination at CWS headquarters, played a central role in shepherding this complex piece of legislation to a successful conclusion. At last, after more than 40 years of repeated efforts, Canada had a federal law in place to govern transport and trafficking in wildlife and wildlife products across interprovincial and international boundaries. In a letter of congratulations to McLean, an enthusiastic Joseph E. (Joe) Bryant, CWS veteran, wrote from retirement:

> Although only a small circle of people will ever fully appreciate what you have accomplished, Canada and Canadians will long be the beneficiaries of your effort.[44]

Anticipating eventual success in amending the Migratory Birds Convention, the Government of Canada also introduced amendments to both the Migratory Birds Convention Act and the Canada Wildlife Act. The amended Acts became law in 1994. Many of the changes reflected concerns that had been raised in the course of the 1993 regulatory review noted above. Of particular interest to wildlife enforcement officers were provisions permitting them to issue tickets for violations of regulations under either Act and prescribing vastly increased penalties for such offences.

Meanwhile, the ongoing negotiations between the United States and Canada came to a successful conclusion on 27 April 1995 at Parksville, British Columbia, where a protocol to amend the Migratory Birds Convention was initialled by the chief negotiators for

The adoption of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) added a new dimension to CWS enforcement duties. In a Customs warehouse in Vancouver, federal game officers Garry Grigg and Ernie Cooper and CITES Identification Contractor Laura Merz display banned objects detained in a single year (Photo credit: E. Cooper).

both countries. The document outlined several key amendments. It accommodated the traditional harvest of migratory birds by aboriginal peoples in northern regions where the birds are present only during that period of the year when the Convention requires that the season be closed. It permitted qualified residents of northern Canada to take migratory game and nongame birds as part of a subsistence lifestyle. It allowed for an earlier fall hunting season for residents of Yukon and the Northwest Territories. It increased the involvement of aboriginal peoples in the study and management of migratory bird populations. It authorized Canada to regulate the harvest of murres in the Province of Newfoundland and Labrador.[45]

The protocol received Cabinet approval in Ottawa in the fall of 1995, and on 14 December, Canada's Environment Minister, the Honourable Sheila Copps, and Bruce Babbit, United States Secretary of the Interior, signed it in Washington. The following summer, the document was forwarded from the White House to the United States Senate, where it received approval on 23 October 1997. As of the 50th anniversary of the Wildlife Service, 1 November 1997, only a few administrative details remained to be clarified before the amended Convention would formally come into effect, marking the conclusion of an 80-year process and clarifying the future terms for regulating the conservation of migratory birds in North America.

Ironically, most of the federal wildlife enforcement coordinators whose dedicated service contributed so much to this outcome were no longer part of CWS. During the early 1990s, the challenges of an expanded enforcement role were further complicated by the ongoing search, throughout Environment Canada, for ways to reduce spending by eliminating duplication of activities within the department. When it was noted that both CWS and the Environmental Protection Branch possessed a mandate for law enforcement, that function became a prime candidate for consolidation. The idea of a unified "green police" to oversee protection of migratory game birds and other wildlife, to govern the import and export of endangered species, and to help control environmental pollution was very attractive. It was determined that a combined enforcement unit could be accommodated within the Environmental Protection Service. A pilot version of the scheme was tested in the Quebec Region, and within a year, even before the conclusion and evaluation of the pilot project, a national Office of Enforcement had been established at headquarters, with the wildlife component headed by Yvan Lafleur.

Most CWS regions, as well as headquarters, opted for this choice, although the integration was only partial. Even within the Office of Enforcement there was a separate Wildlife Division that interacted with CWS on a regular basis, and in the Atlantic and Ontario regions the integrated approach was not implemented at all. A thorough review of options in those regions indicated that the potential savings would be outweighed by the costs of a merger of the sections involved. Thus, by 1997, when a poacher of Canada Geese was apprehended on the Bay of Quinte, a traveller was caught at Toronto's Pearson International Airport smuggling an animal product into Canada in violation of CITES, or a ship was taken into custody for fouling seabird habitat with an oil spill along the coast of Newfoundland, it was still an officer of CWS who laid the charge.

Notes

1. Acts of the Parliament of the Dominion of Canada, *Migratory Birds Convention Act*, 7-8 George V, Chapter 18, Seventh Session, Twelfth Parliament, Volume 1, Public General Acts (Ottawa, 1917).
2. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975).
3. Robie W. Tufts, *Looking Back: Recollections of a Migratory Bird Officer* (Windsor, Nova Scotia: Lancelot Press, 1975).
4. Jack Shaver [retired enforcement coordinator, CWS, Prairie and Northern Region], personal communication, interviewed at Edmonton, 3 December 1996.
5. *Twillingate Sun*, Twillingate, Newfoundland, 1 October 1949.
6. St. John's *Daily News*, 5 November 1949.
7. Unidentified press clipping, Canadian Wildlife Service archival files, Sackville, New Brunswick.
8. St. John's *Daily News*, 19 February 1951.
9. Corner Brook *Western Star*, 20 March 1951.
10. St. John's *Daily News*, 18 April 1951.
11. St. John's *Daily News*, 24 May 1951.
12. A. Huget, "The role of the Royal Canadian Mounted Police in Canada's national wildlife policy and program" in *Transactions of the 31st Federal–Provincial Wildlife Conference*, 11–13 July 1967, Ottawa (Ottawa: Canadian Wildlife Service, 1967), page 30.
13. Huget, "The role of the RCMP," page 31. (See note 12)
14. J. Bryant, personal communication, May 1997.
15. Huget, "The role of the RCMP," page 31. (See note 12)
16. Huget, "The role of the RCMP," page 32. (See note 12)
17. J. A. Stoner, personal communication, telephone interview, 21 January 1998.
18. Stoner, personal communication. (See note 17)
19. Lewis, *Lively*, page 463. (See note 2)
20. David Paul, personal communication, interviewed at Sackville, New Brunswick, May 1997.
21. W. R. Miller, "Aspects of law enforcement in Canada — Migratory Birds Convention Act" in *Transactions of the 31st Federal–Provincial Wildlife Conference*, 11–13 July 1967, Ottawa (Ottawa: Canadian Wildlife Service, 1967), page 35.
22. Miller, "Aspects of law enforcement," page 35. (See note 21)

23. Miller, "Aspects of law enforcement," page 34. (See note 21)
24. W. David Paul, *Confessions of a Duck Cop* (Harvey Station, New Brunswick: Linked Communications, 1996).
25. Shaver, personal communication. (See note 4)
26. F. G. Cooch, S. Wendt, G. E. J. Smith, and G. Butler, "The Canada Migratory Game Bird Hunting Permit and associated surveys" in H. Boyd and G. Finney (editors), *Migratory Game Bird Hunters and Hunting in Canada* (Ottawa: Fisheries and Environment Canada, Canadian Wildlife Service Report Series, Number 43, 1978, pages 8–39). In a personal communication in May 1998, Graham Cooch, who assumed responsibility for hunting permits, surveys, and bird banding permits in 1970, noted that by 1972 Dr. Sen, assisted by G. E. J. Smith and Gail Butler, had developed a new sampling scheme for both the National Harvest Survey and the Species Composition Survey. That scheme has remained in use to the present day. He further observed that 20 years after the Canadian survey system was introduced, United States authorities chose as the model for updating their own surveys the system developed by Cooch and Sen.
27. K. E. Freemark and F. G. Cooch, "Geographical analysis of waterfowl kill in Canada" in H. Boyd and G. Finney (editors), *Migratory Game Bird Hunters and Hunting in Canada* (Ottawa: Fisheries and Environment Canada, Canadian Wildlife Service Report Series, Number 43, 1978, pages 66–77).
28. Stoner, personal communication. (See note 17)
29. Robert H. Scammell, "Keynote address" in *Transactions of the 41st Federal–Provincial Wildlife Conference*, 5–7 July 1977, Winnipeg (Ottawa: Canadian Wildlife Service, 1977), pages 89–100.
30. A. S. Murray, "The management perspective" in *Transactions of the 41st Federal–Provincial Wildlife Conference*, 5–7 July 1977, Winnipeg (Ottawa: Canadian Wildlife Service, 1977), page 104.
31. Richard D. Elliot, personal communication, interviewed at Sackville, New Brunswick, 16 January 1998.
32. L. M. Tuck, *The Murres: Their Distribution, Populations, and Ecology* (Ottawa: Queen's Printer, Canadian Wildlife Service Monograph Series, Number 1, 1961), page 238.
33. Richard D. Elliot, Brian T. Collins, Ellen G. Hayakawa, and Lucie Métras, "The harvest of murres in Newfoundland from 1977–78 to 1987–88" in A. J. Gaston and R. D. Elliot (editors), *Studies of High-latitude Seabirds. 2. Conservation Biology of Thick-billed Murres in the Northwest Atlantic* (Ottawa: Canadian Wildlife Service Occasional Paper Number 69, 1991), page 42.
34. Richard D. Elliot, "The management of the Newfoundland turr hunt" in A. J. Gaston and R. D. Elliot (editors), *Studies of High-latitude Seabirds. 2. Conservation Biology of Thick-billed Murres in the Northwest Atlantic* (Ottawa: Canadian Wildlife Service Occasional Paper Number 69, 1991), page 34.
35. Quoted in J. A. Burnett, "A tale of turr," *Equinox* 60 (November/December): 60–67 (1991).
36. K. Dickson, *1993 April Report on the Status of Migratory Game Birds in Canada with Proposals for 1993 Hunting Regulations* (Ottawa: Canadian Wildlife Service, 1993).
37. *R. v. Sikyea, [1964] 2 C.C.C. 325, 43 D.L.R. (2nd) 150 per* Johnson J.A. (N.W.T.C.A., aff'd. *sub. nom Sikyea v. The Queen*, [1964] S.C.R. 642, 50 D.L.R. (2nd) 80.
38. *Daniels v. White and The Queen*, [1968] S.C.R. 517.
39. Quoted in *Dominion Law Reports*, 81 D.L.R. (3d), page 400.
40. cf. *Regina v. Catagas, Dominion Law Reports*, 81 D.L.R. (3d), pages 396–403.
41. *R. v. Sparrow*, [1990], S.C.R. 1075.
42. Canadian Wildlife Service, *Canadian Wildlife Service Regulatory Review* (Ottawa: Canadian Wildlife Service, discussion document, 1993), page 32.
43. cf. A. M. Scheuhammer and S. L. Norris, *A Review of the Environmental Impacts of Lead Shotshell Ammunition and Lead Fishing Weights in Canada* (Ottawa: Canadian Wildlife Service Occasional Paper Number 88, 1995).
44. Private correspondence, J. Bryant to R. McLean, 24 February 1993.
45. Environment Canada, Background briefing note (Environmental Conservation Service, 1995).

1952–1957: Staking Out the Territory

By the time Harrison Lewis retired in March 1952, he could look back with satisfaction at having successfully guided CWS through its formative years. The original scientific team of nine biologists had grown to 22. Administrative and technical support staff had increased as well. Wildlife Service offices were now located in 14 communities across Canada, from Vancouver to Aklavik to St. John's.[1]

Lewis's successor was Bill Mair, a retired army officer and the charismatic wartime leader of a particularly deadly Canadian/American commando unit.[2] Bill Mair had Bachelor's and Master's degrees in zoology from the University of British Columbia. His immediate task on becoming Chief was not to reinvent the Wildlife Service or even to accelerate its growth. Rather, he had to consolidate it, and this he did with a quiet strategic efficiency reflective of his military background.[3] The job was done against the background of yet another departmental reorganization in 1953, which saw the Department of Resources and Development renamed as the Department of Northern Affairs and National Resources. Beneath the umbrella of that departmental affiliation, CWS remained securely ensconced as one of three divisions of the National

The rigours and isolation of fieldwork in the Arctic during the 1950s are apparent as Graham Cooch examines an overturned komatik (dog sled) with provisions and supplies scattered around him (Photo credit: CWS).

Parks Branch. The other two were the National Parks and Historic Sites Division and the National Museum of Canada. It was an organizational relationship that would endure with little significant adjustment for the next 14 years.

From 1952 to 1957, the growth of CWS was gradual but steady. A 52% increase in budget allocation, from $309 000 in 1952–1953 to $469 000 in 1956–1957, reflected the expanding role of the agency.[4]

The mandate of the service was still expressed in very general terms as dealing "with most wildlife matters coming within the jurisdiction of the Federal Government."[5] Administration of the Migratory Birds Convention Act in conjunction with the RCMP and the provincial game authorities remained a central responsibility. By extension, this was taken to mean that the Wildlife Service could be called upon to represent Canada's national interests in virtually any situation involving wildlife. CWS specialists provided advice on wildlife management to both the National Parks Division and the Northern Administration Branch. The agency also cooperated closely with the provinces, providing coordination and advice on the administration of the Game Export Act.

Much of the research effort in these early days still fell into the category of cataloguing. Wildlife inventories for even the oldest of the national parks were far from complete. Whatever specific projects CWS biologists in the field might have in hand, they were constantly alert to the need for recording general observations as well. For example, between 1953 and 1955, while conducting field studies on Wolves, Caribou, and diseases of Beaver and Muskrats, Frank Banfield incidentally compiled updated bird lists for Banff and Jasper national parks and the Kluane Game Sanctuary as well, publishing them in *The Canadian Field-Naturalist*.[6] At about the same time, inventories of the birds and mammals of Prince Albert, Elk Island, and Riding Mountain national parks, prepared by Dewey Soper, were published as *Wildlife Management Bulletins*.[7] These bulletins, an innovation first introduced under Harrison Lewis, marked the beginning of the CWS tradition of in-house scientific publications.

Quite apart from gathering information on the distribution of species, however, the greater part of the CWS field research effort was focused on some very practical questions. When Canadians spoke of wildlife management in the 1950s, they did so ordinarily in the context of economic activities such as hunting, fishing, and commercial trapping. Annual reports of CWS activities from the mid-1950s indicate three primary areas of interest: waterfowl, mammals (primarily big game and fur-bearing species), and sport fishing in national parks.

The emphasis on waterfowl came as a direct consequence of the Migratory Birds Convention Act. Of all the migratory species covered under the treaty, waterfowl — especially ducks and geese — were the most numerous and the most widely hunted. By the early 1950s, an aerial survey of prime waterfowl breeding areas across Canada had become an annual event, conducted jointly with the United States Fish and Wildlife Service. A yearly inventory of wintering waterfowl, noting abundance, distribution, and condition, also took place in most provinces. Together, the two studies provided data from which population estimates could be derived as a basis for the annual revision of hunting regulations.[8]

The challenge of determining reliable waterfowl census figures over half a continent inspired CWS biologists to devise some innovative research methods. Thousands of birds were colour-marked, banded, or collared in an effort to find the best way to trace their peregrinations. In 1953, aerial surveys were introduced to monitor wintering Snow Geese in the Fraser Delta. By 1956, Bernie Gollop was publishing reports on the use of retriever dogs to capture flightless Mallards for banding in the Prairies. Not coincidentally, one of his articles appeared in the C.I.L. *Oval*, a publication sponsored by one of Canada's principal manufacturers of sporting guns and ammunition.[9]

Even with limited resources to draw on, the work of CWS was widely distributed. While Alex Dzubin and Bernie Gollop concentrated their attention on the ducks of prairie sloughs and potholes, Louis Lemieux and Graham Cooch were among the first in a long line of CWS biologists for whom the Snow Goose populations of the eastern Arctic would be a continuing passion. At the same time, Joe Boyer was monitoring Black Ducks and mergansers in the Maritimes, and Graham Cooch was initiating studies of eider ecology on Baffin Island in the hope that a down collecting industry might be developed as a source of income for the Inuit residents.

Less adventurous than fieldwork, perhaps, but just as essential to the effectiveness of CWS, were the desk-bound duties of analysis and report writing. During the 1950s, much of this work fell to Chief Biologist Vic Solmon, whose office offered a fine view of Ottawa gothic stonework by way of consolation (Photo credit: CWS).

CWS studies in mammalogy took biologists to equally far-flung corners of the country. Within the national parks, where hunting was not an issue, mammalogists focused on range capacity, parasitism, animal pathology, and predator–prey relationships with a view to maintaining healthy breeding populations of large mammals in these protected areas. Culling, range management, and the capture and shipping of live Elk, Moose, Bison, and other species as gifts to zoos were other functions of herd management on which CWS mammalogists provided advice and assistance.

Beyond the boundaries of the parks, much interest centred on the utility of large ungulate species that were important sources of food for aboriginal and other indigenous people of the north. Frank Banfield had begun investigations of the Barren-ground Caribou as early as 1948. John Kelsall assumed direction of the project through the 1950s, and Caribou studies grew steadily in scope and scale, eventually involving more than a dozen researchers.[10] During the same period, John Tener was investigating Muskox.[11] In the eastern Arctic, Alan G. Loughrey pursued ground-breaking work on Walrus[12] until, somewhat to his chagrin, the Department of Fisheries stepped in and claimed that the marine tuskers fell under its constitutional responsibility for "Seacoast and Inland Fisheries."[13] Their action effectively separated Loughrey from the proposed subject of his Ph.D. research.

Because trapping was one of the few sources of cash income available to northern residents, the ecology of fur-bearing mammals commanded the ongoing attention of CWS biologists during the mid-1950s. Muskrats were prime targets for the industry and the subject of population surveys at locations ranging from Point Pelee National Park to the wetlands of the Mackenzie Delta. In the latter region, biologist Joe Bryant followed in the footsteps of Ward Stevens, spending three years (1955–1958) working primarily on Muskrat ecology and management, based in the CWS office at Aklavik.

While ornithologists and mammalogists ranged far and wide across Canada, the work of the CWS fish specialists took place largely within the national parks. The opportunity to pursue recreational fishing in wilderness settings of spectacular beauty had long been recognized as one of the principal attractions of Canada's national parks. Parks Branch fish hatcheries, under the guidance of CWS limnologists, produced hundreds of thousands of trout annually to stock and restock key rivers and lakes.

Vic Solman, the first CWS limnologist, was now Chief Biologist, but his successors, Jean-Paul Cuerrier, J. Clifton (Clift) Ward, and F. Hugh Schultz, were engrossed in a wide variety of studies, ranging from experiments with aerial transportation of live Lake Trout to studies of spawning Northern

Pike. Routine management tasks included the gathering and analysis of creel census data and the eradication of nongame fish from selected waters where they posed a threat of competition or predation on species that were more desirable to anglers.

The rapid pace of technological advancement began to have a noticeable influence on CWS field research methods in the 1950s. One especially interesting innovation, the use of underwater television in freshwater fisheries research, was developed by the limnology section and reported in both scientific and popular publications[14] (see Chapter 5).

Another important overlap that occurred at this time between the worlds of wildlife management and modern technology was the growing recognition of the risk that birds posed to aircraft. Vic Solman had first become aware of the problem while flying for Ducks Unlimited, before joining CWS, and both he and Harrison Lewis had been making public references to it since 1950.[15] Now, in 1952–1953, the problem was addressed from a practical standpoint, in relation to air strikes by gulls at the airport in Yarmouth, Nova Scotia. It was an area of applied research in which CWS was to play a pioneering role for years to come (see Chapter 3).

One of the greatest values of powered flight was as a means of reaching locations that were virtually inaccessible to any other form of transportation. The importance of this was amply illustrated on 30 June 1954, when the reported presence of breeding Whooping Cranes was confirmed in Wood Buffalo National Park by CWS mammalogist Bill Fuller. The nesting grounds of this largest of Canada's breeding bird species had hitherto been unknown. Mechanical flight made possible both the discovery of the site and the subsequent human intervention to rescue the birds from extinction (see Chapter 9).

Two attributes stood out in the array of CWS activities between 1952 and 1957. One was the breadth, depth, and variety of scientific interests that the service took in its stride. The second was the confidence and passion with which CWS personnel pursued not only their own work with wildlife, but also the never-ending task of education and lobbying that was required to build and sustain a supportive public. Scarcely an annual meeting of the North American Wildlife Conference, the International Association of Game, Fish, and Conservation Commissioners, or the Federal–Provincial Wildlife Conference passed without the delivery by senior CWS biologists and administrators of papers that dealt seriously with science and policy alike. By the end of its first decade, CWS had clearly won the attention and respect of its peers.

At the other end of the communications spectrum, many CWS biologists and technicians gave generously of their time in speaking to people in all walks of life — university students, school children and youth groups, service clubs and chambers of commerce, naturalists, trappers, anglers and hunters, farmers, foresters, and law enforcement groups. Many took part in radio interviews or wrote newspaper columns. Often such work was done on their own initiative and their own time. It was simply a very satisfying way of sharing the passion they felt for their work and their country with other Canadians.

Notes

1. *Report of the Department of Resources and Development for the Fiscal Year Ended March 31,1953* (Ottawa, 1953). cf. map glued to inside back cover.
2. J. Bryant, personal communication, interviewed at Ottawa, 26 November 1996.
3. V. E. F. Solman, personal communication, interviewed at Ottawa, 26 November 1996.
4. Canada, Department of Resources and Development/ Northern Affairs and National Resources, *Annual Reports* (Ottawa, 1953–1957).
5. Canada, Department of Resources and Development, *Annual Report* (Ottawa, 1953), page 28.
6. A. W. F. Banfield, "Notes on the birds of Kluane Game Sanctuary, Yukon Territory" and "Additions to the list of Banff National Park birds," *The Canadian Field-Naturalist* 67: 4 (1953); "Notes on the birds of Jasper National Park," *The Canadian Field-Naturalist* 68: 1 (1954); "Further notes on the birds of Banff National Park," *The Canadian Field-Naturalist* 68: 4 (1954).
7. J. Dewey Soper, Canadian Wildlife Service Wildlife Management Bulletin Series 1, Numbers 3, 5, and 7; Series 2, Numbers 3, 4, and 6 (Ottawa: Canadian Wildlife Service, 1952, 1953).
8. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Ottawa: Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), page 329.
9. J. B. Gollop, "Dogs in the duck factory," C.I.L. *Oval* (October 1956).
10. cf. J. P. Kelsall, *Continued Barren-ground Caribou Studies* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 1, Number 12, 1957).
11. J. S. Tener, *A Preliminary Study of the Musk-oxen of the Fosheim Peninsula, Ellesmere Island, NWT* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 1, Number 9, 1954).
12. Alan Loughrey, *Preliminary Investigation of the Atlantic Walrus (*Odobenus rosmarus rosmarus*)* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 1, Number 14, 1959).
13. *British North America Act*, Section 91(2).
14. J.-P. Cuerrier, H. Schultz, and V. E. F. Solman, "Underwater television in freshwater fisheries research" in *Transactions of the Eighteenth North American Wildlife Conference* (1953); and V. E. F. Solman, "Television goes underwater," *Forest and Outdoors* (March 1953).
15. Solman, personal communication. (See note 3)

CHAPTER 3. Working with Birds

"We're for the Birds!"

Over the course of its first 50 years, CWS made many important contributions to the life sciences. Staff members included distinguished mammalogists, limnologists, parasitologists, pathologists, toxicologists, and forest, grassland, alpine, marine, and Arctic ecologists. Amidst this diversity of disciplines, however, one — ornithology — stood out as the preeminent scientific concern of the agency. As Director General Alan Loughrey put it, addressing the 44th annual Federal–Provincial Wildlife Conference, "We are literally 'for the birds.'"[1] Charged with administering Canada's responsibilities under the Migratory Birds Convention, CWS developed an increasingly comprehensive national program to conserve migratory birds, promoted international initiatives for bird conservation, and earned an enviable reputation as one of the world's foremost centres of ornithological research and expertise.

CWS was created on the cusp of a generational turnover in the history of Canadian ornithology. Percy Taverner had retired from the National Museum in 1942 after a distinguished 31-year career.[2] Austin Rand, who had filled Taverner's shoes at the museum during the war years, moved on in 1947 to become Curator of Ornithology at the Field Museum in Chicago. The mantle of responsibility for avian systematics and taxonomy passed to a new generation in the person of W. Earl Godfrey.[3]

The old guard of migratory bird protection had come to a similar turning point. Hoyes Lloyd retired as Superintendent of Wild Life Protection in 1943 after 25 years of tireless commitment to the cause of conservation. His retirement from the public service freed him to pursue his personal interest in ornithology still more avidly. He served as President of the American Ornithologists' Union from 1945 to 1948 and participated actively in the work of the International Council for Bird Preservation until 1972.[4]

The four men whom Lloyd had recruited as Chief Migratory Birds Officers were also at or near the end of their careers in government service. Robie Tufts, eldest of the group, had been named to the post for the Maritimes in 1919. Tufts was forever a keen naturalist, observer, and collector. Following his retirement in 1947, he was able to devote much more time to a study of birds that culminated in the initial publication of *Birds of Nova Scotia* in 1961 and a revised second edition in 1973.[5]

Jim Munro was the next to retire. Appointed in 1920, he reached the retirement age of 65 in 1949. The west having been settled more recently and the hunting pressure on game birds being correspondingly less intense, Munro was more able than Tufts to devote a significant proportion of his working career to studying the life history and ecology of birds. His contribution to Canadian ornithology is illustrated by more than 100 published articles.

Dewey Soper spent fewer years than his colleagues in the role of Chief Migratory Birds Officer, having been officially appointed in 1934.[6] Prior to that date, however, he had conducted five major expeditions to the Northwest Territories as a contracted explorer and naturalist for the National Museum. Letters to Taverner during that period reveal the depth of his enthusiasm. In 1929, he wrote from southern Baffin Island:

> As a bird migration route and breeding grounds [this] eclipses by far anything I have ever beheld in the past. Think of a region swarming with Blue Geese..., and around camp to have such birds commonly nesting as Red Phalarope, White-rumped Sandpiper, Parasitic and Long-tailed Jaeger, Black-bellied and Semipalmated Plover, Ruddy Turnstone, King Eider, Black-throated Loon, Sabine's Gull and — a little removed, Blue and Snow Geese! Yes indeed, it has been a great experience, especially during the migration, with thousands upon thousands of these birds and others swarming over the snow-free patches of tundra on their way to higher latitudes.[7]

Soper retired from CWS in 1952. He had been formally employed as a federal wildlife officer for only 18 years, but a bibliography of more than 100 articles and reports (41 of them on birds) that he published over a 64-year span between 1917 and 1981 underlines his lifelong dedication to expanding the frontiers of Canadian ornithology.[8]

Of all the members of the old guard, Harrison Lewis had the longest career in federal wildlife protection work — over 31 years from his appointment in November 1920 to his retirement in April 1952. As Superintendent of Wildlife Protection for Canada (1944–1947), as Chief of the Wildlife Service (1947–1952), and as author of some 326 scientific and popular publications, Lewis established high standards of performance and of scholarship. In an obituary tribute published in the *Canadian Field-Naturalist*, Vic Solman wrote:

> Dr. Lewis had a strong influence on the biologists with whom he came in contact. He was always well informed and precise and was an excellent writer and editor. Many of us, including the author, learned a great deal about research methods, research reporting, and the use of the English language under his kind but firm instruction. The ideas he left behind and the habits he helped many of us to form, will ensure that for a long time he will be in our minds as a great leader, encourager, and example.[9]

Lewis's sphere of influence as an ornithologist extended at times beyond his immediate colleagues. His base of operations, when he was not patrolling the Gulf of St. Lawrence, was Ottawa. One day in 1937, a boy about nine years of age came into the Ottawa

South Public Library to ask for books on birds. The librarian made a number of suggestions, but the lad rejected them all as inadequate. At this point, a middle-aged woman who had been listening to the exchange with growing amusement turned to the boy and said, "Why don't you come over to my house this afternoon? My husband knows a thing or two about birds." The woman was Harrison Lewis's first wife, Blanche. The boy was Graham Cooch, who, in that afternoon's encounter, gained a mentor who would steer him into a lifelong career in ornithology.[10]

Lewis was by no means the only member of the old order to inspire potential successors. About a year later, in Wolfville, Nova Scotia, a boy named Anthony J. (Tony) Erskine knocked shyly at Robie Tufts' door and asked if he might "see the bird collection."

> We had got Taverner's *Birds of Canada* for Christmas the year before and I had just devoured it. I went to see the collection one day on my way back to school after lunch. I was fascinated by it and, as a result, was late for school. For my punishment, the teacher made me stand up and tell the class what I had seen, which so unnerved me that I didn't stand up and talk about birds in public again for another 20 years.[11]

Like Cooch, Erskine would grow up to occupy a distinguished place among CWS ornithologists.

The biologists whom Lewis enlisted to staff the Wildlife Service after 1947 were representative of an energetic new breed. Although young, many were veterans recently returned from military service in the Second World War. They were accustomed to discipline, yet possessed independent minds and a spirit of initiative that would serve them well in wilderness field camps. They also differed from their predecessors in one very significant way. They were trained biologists when they were hired, some with Master's or doctoral credentials. Lloyd and his colleagues had exemplified the virtues of the Victorian amateur naturalist. Of the five of them, only Dewey Soper actually had a degree in zoology. Lloyd's was in Chemistry, and although Lewis later earned a Ph.D. in ornithology for his work on cormorants, he had only a general B.A. when he became a Chief Migratory Birds Officer.

In Lewis's view, a sound wildlife conservation and protection program must be based on accurate observation and sound scientific analysis. He strove to recruit and train a team for the new agency whose approach would be at once open-minded and dependable. With limited resources at his disposal, his method was simple and direct. He hired the best candidates he could find, set them demanding tasks, and accepted nothing less than excellence in their performance.

Avian and Human Interactions

Good science could produce creative approaches to wildlife management problems. In the summer of 1947, for example, David Munro was sent to Saskatchewan as a summer student to work under Dewey Soper's supervision on the problem of crop damage by Sandhill Cranes. Once there, he made two key observations. First, the birds were doing more harm by trampling grain than by eating it. Second, the damage was concentrated, for the most part, on marginal land bordering the salt flats adjacent to Last Mountain Lake, a key stopping point for the birds on their southward migration. Given the low agricultural value of the land, Munro made a three-part proposal: buy the property in question and establish it as a protected area; plant it in lure crops to concentrate the offending birds; and permit shooting, if necessary, if cranes wandered outside the lure crop zone. The idea of purchasing critical habitat for management purposes was viewed as highly unconventional at the time. Nevertheless, it lodged in Munro's memory and gave rise 20 years later, when he was Director of CWS, to one of the central themes of the National Wildlife Policy — the concept of the National Wildlife Area (see Chapter 6).[12]

During the early years, circumstances dictated that most CWS wildlife and migratory bird officers be generalists, ready to conduct waterfowl brood surveys or assess range conditions for ungulates with equal alacrity. Thus, Joe Boyer, the sole Wildlife Service representative in the Maritimes in 1947, found himself reporting on a range of topics that ran the gamut from waterfowl harvest statistics and the results of a Maritime Woodcock census to the status of game and fur-bearing mammals in the region and the fact that Prince Edward Island had paid bounties on 46 327 skunks and 1092 Snowy Owls between 1932 and 1943.[13] In a similarly eclectic vein, between 1951 and 1953, Dewey Soper published a total of seven titles in the *Wildlife Management Bulletin* series, summarizing waterfowl investigations in the Peace–Athabasca Delta region of northern Alberta and reporting on the birds and mammals of Elk Island, Prince Albert, and Riding Mountain national parks.[14]

Few people in the 1940s saw wildlife from a holistic point of view. Like trees and minerals, birds, mammals, and fish were generally viewed as resources to be responsibly managed for the purpose of generating long-term economic returns. Unlike trees and minerals, however, birds are mobile and not infrequently engage in behaviours that may compete or conflict with human interests. What to do about predation by birds on crops and other economically important resources was a long-standing theme for CWS. A significant amount of ornithological research, like that of David Munro at Last Mountain Lake, was dedicated to investigating and resolving such problems.

Studies to assess the real impact of damage by birds and to devise strategies to minimize it predated the formation of the Wildlife Service. As early as 1915, Taverner had explored the impact of seabirds on fisheries in the Gulf of St. Lawrence. In the 1930s, Jim Munro was evaluating the extent to which mergansers might limit salmon stocks in British Columbia rivers.[15] It was a topic that would not go away. Despite a dearth of evidence that waterfowl had any significant influence on fish stocks, migratory bird regulations permitted hunters to shoot 25 American or Red-breasted Mergansers in addition to their bag limit of other species. That concession remained on the books until the mid-1950s, when Bill Mair, then Chief of CWS, reviewed the available literature, ruled that he could see no justification for the allowance, and wiped it off the books.[16] Fisheries managers were reluctant to concede the point, however, and one of Tony Erskine's first assignments after joining CWS in 1960 was the study of predation by mergansers on Atlantic Salmon on the Margaree River.[17]

Wherever there were crops, the complaints of farmers had to be balanced against the conservation goals of the Migratory Birds Convention Act. It was a recurring theme, especially in the Prairie provinces, during the mid-1960s, when the Canada Land Inventory initiative was assessing the relative value of land for agricultural production and for wildlife habitat. Crop damage was also the central issue in R. G. B. (Dick) Brown's first CWS assignment, in the late 1960s, to study bird damage to fruit crops in the Niagara Peninsula.[18]

Latterly, the destruction of emergent grain and hay crops by Snow Geese has become a matter of growing concern along the St. Lawrence Valley. The vast flocks of white geese are a powerful attractant to ecotourists at centres such as Montmagny, Cap Tourmente, and Baie du Febvre. On the other hand, farmers in the Quebec City area complain that grazing by the birds on new growth during the spring migration has resulted in reductions of as much as 24% in some hay crops.[19]

In coastal regions, CWS has responded to a marine variation on the crop damage theme. With the growth of the aquaculture industry, the fact that young blue mussels are a favourite prey of eiders and other seaducks has become a serious cause for worry among shellfish growers. Since 1989, research on this aspect of bird behaviour has been undertaken in British Columbia,[20] Nova Scotia,[21] and Newfoundland.[22]

Another area of avian–human conflict on which CWS did ground-breaking research was the question of collisions between birds and aircraft. Vic Solman's work with Ducks Unlimited had alerted him to the existence of this problem when an aircraft in which he was flying a waterfowl survey in 1941 collided in mid-air with a duck. The impact ripped a hole in the wing of the plane, dangerously close to a fuel line. From 1942 to 1945, his wartime experience with the Royal Air Force Ferry Command in Canada gave him a more complete insight into the extent of the problem.

Harrison F. Lewis began the census of colonial seabirds on the Lower North Shore of the St. Lawrence in the early 1920s. In recent years, the ongoing responsibility has passed to CWS biologist Gilles Chapdelaine, seen here weighing a Black-legged Kittiwake on Île du Corossol (Photo credit: CWS).

After the war, Solman's duties with the Wildlife Service included investigation of major bird strikes and provision of advice as to how to avoid them. As data accumulated across the country, patterns began to emerge. Since the presence of birds in the vicinity of runways constituted a hazard, common sense suggested ways to deter them from gathering at airports: cut tall grass, trees, and shrubs beside runways; and eliminate insect pests that might attract feeding flocks of birds. A variety of devices and techniques, ranging from noisemakers to the flying of trained falcons, were employed with varying degrees of success.

The matter took on greater urgency in the early 1960s, following two incidents in the United States in which collisions between aircraft and migrating flocks of birds resulted in multiple human fatalities. Birds in flight could not be reliably controlled or diverted. To minimize such encounters, it was necessary to learn a lot more about patterns of migration. One of the legacies of the Second World War was an excellent tool for gathering this information — radar. Radar installations across Canada could monitor bird movements, identifying the times, conditions, locations, and directions in which birds and aircraft might meet. By a judicious combination of scheduling, rerouting, and the issuance of warnings to pilots, the frequency and seriousness of midair strikes by military aircraft fell sharply. Department of National Defence officials told Solman that the measures saved them an estimated two CF-104 fighter planes per year. Mitigative efforts at airports reduced the risk to civilian aircraft as well. Between 1963 and 1967, the cost to Air Canada for parts to repair bird strike damage to aircraft dropped from $238 000 to $125 000 per year.[23]

CWS did not work alone on the bird strike problem. The Associate Committee on Bird Hazards to Aircraft, convened by the National Research Council's aircraft engine laboratory, included representatives of the Wildlife Service, Defence, and Transport, as well as airlines, manufacturers, and the Canadian Airline Pilots Association. The work of the committee, although focused on Canada, was applicable wherever birds and aircraft might share airspace. The International Civil Aviation Organization followed it with interest. Contact between Associate Committee members and their colleagues in other countries led to the creation of a European committee in 1966 and to a World Conference on Bird Hazards to Aircraft, attended by delegates from 21 countries, in 1969.

Vic Solman continued to play a central role in the bird strike issue, serving as chairman of the Associate Committee on Bird Hazards to Aircraft from 1964 to 1976.[24] In 1967, he recruited a fellow committee member to become a valuable CWS colleague. Hans Blokpoel, biologist and former pilot in the air force of the Netherlands, joined enthusiastically in the task of gathering, assessing, and interpreting data. His book on the subject, *Bird Hazards to Aircraft*, published in 1976, has become a standard reference work in many countries.[25]

Meanwhile, the bird strike problem continued to manifest itself around airports near major urban centres. After Solman's retirement, Blokpoel maintained a professional interest in the subject, in conjunction with his study of gulls and terns in the Great Lakes. The sharp increase in the population of Ring-billed Gulls in the Toronto area, to cite one example, stimulated a need for further study of preventive measures.[26]

Waterfowl

It is no exaggeration to say that ducks and geese dominated the ornithological agenda at CWS, at least during the first 20 years after 1947. Indeed, it was suggested by some, and not always kindly, that the initials of the agency really stood for Canadian Waterfowl Service. The reason for this perceived bias was straightforward enough. The principal legislative raison d'être of the service was the Migratory Birds Convention Act, which placed a considerable emphasis on the conservation of game birds. Waterfowl were by far the largest and most sought-after group of migratory game birds under its protection. An important element in the discharge of that responsibility was knowing the approximate size of waterfowl populations and whether they were growing or declining. As David Munro and Bernie Gollop observed:

> In January, all but a minute proportion of North American waterfowl may be found south of the Canadian boundary; in July about 70% of the population is north of that line. Generalities based on these facts have been frequently stated and are widely known....Because of [the Migratory Birds Convention] the Federal Governments of Canada and the United States are presently engaged in waterfowl research.[27]

Ground crews had attempted to conduct surveys of breeding waterfowl as early as the 1930s, but the size and accuracy of the samples, while informative about local conditions, could not support generalizations across large areas. In 1947, a duck-banding station was established at La Baie-Johan-Beetz, on the north shore of the St. Lawrence, but only as small aircraft became more readily available for survey work did large-scale population research become feasible. Even then, for many years it was the United States Fish and Wildlife Service that had the equipment and resources to conduct aerial transects, while CWS crews did the on-site verification on the ground. Gradually, however, Canada assumed a more active role. Arctic mammalogists such as Frank Banfield, Alan Loughrey, and Bill Fuller were already making extensive use of aircraft to count Caribou, Walrus, and Bison. Eventually, the evident value of such a practical tool in biometric research resulted in Canadians taking on a larger share of waterfowl surveys in Canadian airspace.[28] After the introduction of the migratory birds hunting permit in 1966, even hunters were pressed into service as informants. Each year, selected permit holders were asked to complete questionnaires and submit wings from the birds they had killed to permit accurate correlation of bag composition data with the number and distribution of participants in the hunt.

The most intensive waterfowl survey efforts were focused on the Prairie "duck factory." Few were the CWS staffers and summer students, apart from those in the high Arctic, who did not find themselves pressed into service from time to time to participate in the annual duck census, a fact-finding task on which decisions about continental bag limits for the coming year would be based. Joe Boyer, Oliver

The work of Vic Solman and Hans Blokpoel on how to avoid collisions between birds and aircraft led to innovative uses of equipment. Here summer student Wayne Gemmell aims a radar, usually used to track weather balloons, at a flock of migrating Snow Geese (Photo credit: H. Blokpoel).

Hewitt, Jim and David Munro, Dewey Soper, George Stirrett, John Tener, and Vic Solman all participated in early CWS waterfowl surveys.

Some parlayed the experience into a life's work. In 1949, Bernie Gollop became the first CWS biologist to be stationed in Saskatoon. He remained in that office until his retirement in 1987. Among others who, like Gollop, earned international reputations for their work on prairie waterfowl were George Hochbaum and Alex Dzubin. By the mid-1960s, their work and that of their CWS colleagues on the prairies had gained sufficient recognition that a dedicated research facility, the Prairie Migratory Bird Research Centre, was established in Saskatoon. Some 70 Canadian and American waterfowl biologists attended a major seminar on wetlands in February 1967 to mark the official opening.[29] In his introductory remarks, David Munro, then Director of the Wildlife Service, stated:

> We now know that the sloughs and potholes of southern Alberta, Saskatchewan, Manitoba, and adjacent parts of the Dakotas and Montana are the breeding habitat for over two-thirds of the continent's most sought-after ducks....
>
> We recognize that we are concerned not with ducks alone but with the management of an environment. Our point of departure is the prairie as habitat for ducks, but it is quite clear that we cannot solve the problem of waterfowl maintenance without an understanding of the ecological and economic characteristics of cereal culture, the social and economic implications of recreation, and the physical nature of ground water flow and evapotranspiration, to name but a few aspects of the prairie environment.[30]

However, as Graham Cooch noted in a paper delivered on the same occasion:

> As yet, we really know little about the habitat requirements of most species of ducks: the degree to which ducks can be crowded, the degree to which they can be pushed from optimum habitat to areas of lower quality and still have high reproductive success in terms of net increment to the autumn flight, the degree to which available habitat can be modified to produce an increased yield of ducklings, the role of inter- and intraspecific competition in regulating reproductive success. I think that these points are important in any attempt to forecast our requirements for waterfowl habitat in the future.[31]

Such questions would consume the energies of Gollop and his colleagues for many years. In the 1980s, the Prairie Migratory Bird Research Centre program was revitalized by the appointment of Antony W. (Tony) Diamond, who led it into new science initiatives. Latterly, Robert (Bob) Clark has played a key role as senior research scientist, promoting partnerships that link CWS interests with those of hydrologists and other wetland specialists. Since the late 1980s, too, cooperative funding and partnerships under the Prairie Habitat Joint Venture of the North American Waterfowl Management Plan (NAWMP), as well as other joint ventures across Canada, have stimulated extensive projects in waterfowl habitat restoration and conservation (see Chapter 6).

Waterfowl work was by no means limited to the prairies. Banding and a wide variety of other techniques were used to gather data and gradually fill in blanks in the puzzle of migratory waterfowl behaviour in all regions. Myrtle Bateman's work with numbered collars on Canada Geese in the 1980s was a good example of this, as was Gerald R. (Gerry) Parker's use of radiotelemetry to track Black Ducks. As early as the 1950s, Louis Lemieux and Gaston Moisan were examining migration and mortality rates of the Black Duck.[32] Since 1968, André Bourget added extensively to knowledge about waterfowl populations in the Gulf of St. Lawrence, assisted in later years by Pierre Dupuis, Denis Lehoux, and Jacques Rosa.[33]

Austin Reed, who began his research career working on Black Ducks for the Government of Quebec, brought that interest with him when he joined CWS in 1969. Subsequently, he worked on Brant, Snow Geese, Canada Geese, and eiders in the Arctic. His experience with aboriginal peoples facilitated the development of joint studies on Common Eiders with Inuit hunters in northern Quebec. This work resulted in the publication of a comprehensive review of traditional Inuit knowledge on the ecology of eiders.[34] Reed was also involved in the discovery of a hitherto unknown colony of Surf Scoters nesting on a lake about 80 kilometres north of Quebec City. Scarcely more than half a dozen nests of this species had previously been found. The presence of such an accessible colony enabled Reed to make fundamental new contributions to knowledge of a species whose life history had been little known and less understood.[35]

Several CWS biologists produced extensive original research on single species of waterfowl. In this category, Tony Erskine's monograph on Buffleheads,[36] which he researched in the 1960s, stands out as a major work. From 1978 to 1985, Jean-Pierre L. Savard's research, particularly in the Pacific and Yukon Region, expanded knowledge of Barrow's and Common goldeneyes.[37] During the 1980s, Savard was also working with Harlequin Ducks on the Pacific coast, while R. Ian Goudie was successfully demonstrating that the Atlantic coast population of the same species was at risk of extirpation.[38] Later, transferring from the Pacific and Yukon to the Quebec Region, Savard took up the study of scoters, locating nesting grounds on the eastern shore of Hudson Bay.[39] Goudie, meanwhile, accepted a transfer to British Columbia.

Among the many summer students who did legwork on prairie waterfowl surveys in the late 1940s, Graham Cooch was one who would have an important effect on the future of ornithology at CWS. The thirst for knowledge about birds that had brought him to Harrison Lewis's door a decade earlier now led him to Manitoba potholes. Over the next few years, it would take him east and north, first banding Black Ducks on the Labrador coast and later conducting Arctic research on Snow Geese that would earn him a doctorate and a full-time job as a CWS ornithologist.

Reputed to attack every activity with relentless energy, Cooch nearly ended his career while on a field expedition in the eastern Arctic in 1962. At the age of 34, he suffered a heart attack and might have died in the field had Al Hochbaum, who was working with him, not prevailed upon their Inuit guides to transport him to a point where he could be flown out for medical attention.[40] The incident marked the end of remote field projects for Cooch. CWS management, unwilling to risk a second crisis so far from assistance, assigned him to desk work, first in setting up a toxicology program (see Chapter 8) and then, in 1964, as Chief Ornithologist. Their concern was by no means fanciful. In 1960, at a conference of eastern CWS biologists near Morrisburg, Ontario, Joe Boyer had been fatally stricken by a cerebral hemorrhage while out duck hunting one morning with David Munro and Hugh Schultz.[41]

As Chief Ornithologist, Cooch was in a good position to ensure that CWS interest in Arctic goose studies, initiated by Dewey Soper in the 1920s and sustained by his own work in the 1950s and 1960s (not to mention that of W. J. D. (Doug) Stephen, Alex Dzubin, T. W. (Tom) Barry, and Hugh Boyd), was not abandoned. He actively supported a number of new research initiatives in this field. Over the years, George Finney, Kathryn E. (Kathy) Freemark, Richard Kerbes, Lynda Maltby, and Pierre Mineau were among numerous young CWS biologists who gained valuable research experience working with geese in Canada's north. Lynda Maltby's 1975 project had the additional distinction of being conducted by the first all-female field party ever sent to the Arctic by the federal government. Besides Maltby herself, the group included Lynne Allen (now Dickson) and Barbara Campbell.[42] In the evolution of a traditionally male-dominated organization, this was a significant milestone.

Perhaps the most significant long-term commitment to northern goose research was the support of Fred Cooke's Snow Goose research camp at La Pérouse Bay in northern Manitoba. Cooke, a geneticist at Queen's University, was initially interested in refining the understanding of the genetic relationship between Blue and Snow geese. Cooch, along with Hugh Boyd, who joined CWS in 1967 as head of research for eastern Canada and later served as Director of Migratory Birds, was able to provide essential core funding for the project, which began in 1968 and continued under Cooke's leadership for about 25 years. An appreciation of its significance may be drawn from the fact that, in 1990, the American Ornithologists' Union saw fit to present

Concern over declining populations of the Black Duck in eastern Canada led to a decade of concentrated banding and research on this species between 1981 and 1991. One of the principal participants in this work was biologist Myrtle Bateman, shown here at a 1985 field camp at Indian House Lake, Labrador (Photo credit: K. Dickson).

Cooke with the William Brewster Award for his leadership of "the most meritorious body of work on birds of the Western Hemisphere published during the previous ten calendar years."[43]

Cooke left the La Pérouse Bay project in 1993, but Snow Goose research has continued to be an active field. In recent years, the more southerly populations of this species expanded rapidly. At La Pérouse and Eskimo Point and many other breeding locations, the increase in the number of nesting pairs has outstripped the carrying capacity of the range. Hugh Boyd, now Scientist Emeritus at the National Wildlife Research Centre, has followed this phenomenon since the 1970s:

> In the southern locations, the geese are devastating large portions of their nesting grounds. That sort of damage might recover quite quickly in a temperate climate, but in the Arctic, once you chew up a grazing area, it may take a hundred years to regenerate. When Lynda Maltby and I were looking at Snow Geese in the high Arctic, it was obvious that those northern geese had adopted a somewhat nomadic lifestyle. They return to a different nesting site each year, whereas the southern geese return to the same site year after year.
>
> I think the southern geese nesting around Hudson Bay used to do the same thing. The trouble is that now there are so many geese that there aren't the unoccupied spaces to move to. When I was flying in the north in the early 1970s, we looked at large parts of Baffin Island that looked perfectly good in July and August but had no geese. When I was back there in 1988 and 1992 with Austin Reed, the whole area had filled up.
>
> Now, that's in the area where Sir John Franklin met his end, and it was traditionally one of the coldest spots in the Arctic. In recent years, satellite images show that the ice in this area has been opening up as much as 10 days earlier than it used to. You have all these birds returning in great shape for breeding. They've been well fed on the leavings of modern agriculture, and they're ready to produce large, strong broods that will thrive in that milder climate, at least until the summer grazing runs out. Today, there are so many Snow Geese being produced that they have totally swamped the capacities of a declining population of hunters. It's a very modern problem.[44]

Seabirds

Waterfowl may have absorbed the attention of more CWS biologists and technicians than any other group of birds, but for a small group of researchers, seabirds have been the abiding passion. This was true of Harrison Lewis himself, who in 1925 initiated a series of quinquennial surveys of seabird colonies along the north shore of the Gulf of St. Lawrence. That tradition has continued, almost unbroken, for more than 70 years, leading to the accumulation of one of the longest-running seabird databases in the world. Although many CWS seabird biologists participated in this survey, it has been the particular responsibility of Gilles Chapdelaine since 1975, assisted by Pierre Laporte, Pierre Brousseau, Jean-François Rail, and others.[45]

A trend towards recovery from the depredations of hunters and egg collectors has been observed in recent years among many seabird populations of the Gulf of St. Lawrence. The effectiveness of the bird sanctuaries established early in this century at the urging of Taverner and Lewis has been extended by the creation of national parks (Forillon and Mingan Archipelago), provincial parks (e.g., Bic), and wildlife reserves (e.g., Anticosti). CWS has acquired a number of important coastal marshes and nesting islands, and various voluntary organizations have joined in the task. Some date back to the 1920s and 1930s, when Harrison Lewis was encouraging organizations such as the Quebec Society for the Protection of Birds and the Provancher Natural History Society to help secure suitable properties as seabird sanctuaries. Since 1975, a positive influence has been the Quebec–Labrador Foundation, a non-profit group dedicated to conserving wildlife and habitat in this region (see Chapter 7). After more than 20 years of Quebec–Labrador Foundation camps and other information programs, local attitudes towards seabirds have changed profoundly. As a result, populations of murres, kittiwakes, eiders, and other colonial seabirds have a much better chance of prospering than in the 1970s.

Among the many people who have influenced human populations in Atlantic Canada to respect living seabirds more than roasted ones, Les Tuck of Newfoundland occupies a place of honour. Reference has already been made (see Chapter 2) to the remarkable combination of intimate knowledge and gentle diplomacy that enabled him to begin weaning rural Newfoundlanders from their cherished tradition of hunting seabirds and seabird eggs. Those qualities also served him well as an ornithologist. To David N. Nettleship, who first worked as a summer student for him in 1965, Tuck was teacher, exemplar, and mentor par excellence:

> You can't say enough about Tuck's generosity and his hospitality. He was a naturalist in the true sense, who had such a broad base of knowledge and was so free in sharing it. My vision will always be coloured by my first sight of him, hiking across the bogs of Newfoundland, knee-deep in gunk, dressed in khaki shirt and pants, with a couple of mist nets over his shoulder and one in an endless succession of cigarettes clamped firmly between his lips.[46]

Motivated by a desire to discover more about the birds he was sworn to protect, Les Tuck was the first CWS ornithologist to make a detailed study of Thick-billed Murres, the "turrs" so beloved by Newfoundlanders. His research took him north for several summers in the 1950s to count and observe the murre colonies on Akpatok Island, Digges Island, and Bylot Island. Ultimately, his findings were published as the first book-length monograph ever released by CWS.[47] *The Murres* not only provided sound data on which to begin managing the turr hunt, but also laid the foundation for the CWS seabird research program that began in the early 1970s.

In fact, it was Hugh Boyd, primarily a waterfowl biologist by training and experience, who recognized the importance of extending the range of CWS ornithological activities to other types of migratory birds in a purposeful manner. Having been Resident Biologist at the Severn Wildfowl Trust in England since 1949, Boyd was in mid-career when he came to Canada in 1967 to take up the position of Research Supervisor of Migratory Birds in Eastern and Arctic Canada.[48] As he himself recalled:

> Those were expansive days. I saw it not just as a chance to add more bodies, but to add greater breadth of interest. Hitherto, with the exception of Les Tuck, CWS had been almost exclusively a waterfowl service, and the huntable species were viewed as almost the only ones worth study or management. Though I was a waterfowl specialist myself, I felt the Migratory Birds Convention Act covered a wider range than that, and I felt we should reflect that fact in our scientific base....I guess we were less bound by departmental views in those days than we are now, so people had more leeway in doing things that mattered, regardless of whether they were in the mission statement or not....I even had a chance to do some of my own research, largely thanks to Joe Bryant's urging as Supervisor of the Eastern Region. He was always egging me on, which was a good break from civil service conventions.
>
> At any rate, I undertook to hire new specialists. Dick Brown had been hired to do work on crop damage in the orchards of southern Ontario, but he became part of the seabird team within two years of my arrival. He went to sea on other people's boats and did some very difficult work on offshore distribution of birds. A real pioneer!
>
> There was also David Nettleship who had been doing a thesis on puffins in Newfoundland. He seemed to be one of these energetic types who might be able to stand up to Les Tuck and devise his own program.[49]

Nettleship did indeed devise his own program, completing his puffin work on Great Island, Newfoundland, extending murre research into the high Arctic with surveys on Prince Leopold Island, conducting research on Northern Gannets and Double-crested Cormorants, developing standardized census techniques for seabird surveys, and coediting *The Atlantic Alcidae*, a book on the evolution, distribution, and biology of the auks of the Atlantic Ocean.[50] Until his retirement in 1998, he continued to play a leading role in the CWS seabird program as an uncompromising research scientist, a prolific writer and editor of scientific papers, and a willing collaborator with the popular media in projects aimed at increasing public awareness of seabird ecology.

He was far from alone in the seabird field, however. While Nettleship was scanning cliffs to count murre chicks, Dick Brown was tossing on the decks of various research vessels belonging to the Canadian Coast Guard or the Bedford Institute of Oceanography. Equipped with a sharp wit, a keen intelligence, and a doctorate from Oxford, Brown had come to Canada in the mid-1960s to teach in the Psychology Department at Dalhousie University. His real interest, however, was the offshore distribution of seabirds. He became so adept at this specialty

The Snow Goose has been a subject of fascination to many CWS researchers since 1947. Here, Dick Kerbes and Jean Venet round up a group to be banded, on Bylot Island, NWT, in the late 1960s (Photo credit: D. Muir).

that, with a glance at the composition, abundance, and behaviour of flocks of birds at sea, he could often predict changes in oceanographic fronts faster than the ships' monitoring instruments could deliver their reports. Perhaps the most important published works among many to come out of this remarkable research effort were the *Atlas of Eastern Canadian Seabirds* (1975)[51] and the *Revised Atlas of Eastern Canadian Seabirds* (1986).[52] Other projects included investigations into the ecology of pelagic species such as fulmars, shearwaters, and phalaropes, as well as work on tracking oil spills and assessing their effects on seabirds.[53] In addition, Brown contributed occasional, witty columns to the *New York Times* and appeared regularly in *Nature Canada*. He also wrote an intriguingly imaginative work documenting the encounter of the *Titanic* and the iceberg, much of it from the iceberg's point of view. The book is an outstanding contribution to popular understanding of northern marine ecology.[54]

A third member of the Bedford Institute of Oceanography-based seabird team from the 1970s onward was Anthony R. (Tony) Lock, who had been studying the energetics of zooplankton until Dick Brown convinced him to look at seabirds. As a result, he did his doctoral research on gulls on Sable Island. Lock's full-time employment with CWS began in 1975 as a duck surveys biologist, although he had performed the North Shore seabird survey in 1972. Later, in 1978, he commenced a five-year stint conducting aerial surveys of seabird colonies along the Labrador coast:

> That was probably one of the last times and places where you could do new exploration anywhere in Canada. You'd just hop in the float plane and take off up the coast. If you got hungry, you'd set down on a lake, step out on the pontoon, and catch an 18-inch char for lunch. At times you had to get in closer than a plane would allow. One season I was dropped off in the Galvano Islands with a Zodiac and enough gas to follow the coast south to Saglek [editor's note: approximately 400 kilometres]. The sense of separation from the rest of the world was tremendous. I visited Eclipse Harbour and found, virtually untouched, the campsite of an American party that came there to observe the solar eclipse of 1851.[55]

During the 1980s, Lock focused much of his attention on the question of population growth among Black-legged Kittiwakes and Ring-billed Gulls. More recently, as a marine issues biologist, he became particularly concerned with the impact of human activities on seabirds. This work led to publication, in 1994, of the *Gazetteer of Marine Birds in Atlantic Canada*, a joint effort of Lock, Brown, and S. H. Gerriets to correlate seabird distribution with shipping activity in order to demonstrate the vulnerability of birds to oil pollution.[56]

By the mid-1970s, Hugh Boyd's ongoing support and David Nettleship's energy had made the seabird program one of the fastest-growing areas of specialization in the Wildlife Service. As interest grew in oil, gas, and mineral exploration in Atlantic Canada and the eastern Arctic, the need for an accurate picture of the wildlife resources of these vast regions was becoming acute. Nettleship recalls the first instance when CWS intervention succeeded in stopping a potentially disastrous industrial development in a sensitive area:

> Our very first test as a program was not with oil but with minerals. A company wanted to develop a lead/zinc operation in Strathcona Sound. I went to the assessment hearings and was told that a month-long study had determined the area to be devoid of life. On the strength of that they intended to dump mine effluent straight into the Sound for the next 20 years. When I probed, I found that the month of research had been done by two Master's students who were simply told to go and evaluate the area. My literature search had already determined that a colony of about 100,000 breeding pairs of fulmars had been found nearby, so I lit into these guys. I said, "You know absolutely nothing about Strathcona Sound. We know of at least one major colony of a top trophic feeder that is dependent on large quantities of fish and crustaceans to feed its young. If fulmars are breeding there, that is proof that this area is biologically very active."
>
> The proponents had expected approval without opposition, but we stopped it. The mine did go ahead, but wastes had to be confined to a landfill. As far as I know, that was the first Arctic assessment exercise where we were able to prevent the ocean dumping of wastes.[57]

In 1975, Gilles Chapdelaine and A. J. (Tony) Gaston were added to the seabird team. Both launched rapidly into studies, surveys, and banding work at murre colonies in the eastern Arctic. In 1981, Gaston and Nettleship produced their major CWS monograph, *The Thick-billed Murres of Prince Leopold Island.*[58] Starting in the mid-1980s, Gaston became involved, with others, in a demographic study of Thick-billed Murres on Coats Island. This ongoing work has provided vitally important data for population modelling and the tracking of environmental change in an area that is otherwise rarely visited.[59]

Conducted on rocky coasts and rough seas, seabird research is not without risks. Over the years, two researchers have died in field accidents — CWS employee Gordon Calderwood in Newfoundland, and graduate student Anne Vallée on Triangle Island, British Columbia. On one occasion in the early 1980s, Gaston himself came perilously close to a similar fate when he fell partway down a cliff on Digges Island before coming to rest on a ledge. With injuries too severe to permit any attempt at escape, he lay there for the better part of a day waiting for a rescue helicopter to reach his location from an ice-breaker in Hudson Strait.[60]

Fortunately, young birds are better designed than biologists for falling from cliffs. One of Gilles Chapdelaine's most vivid memories is of standing at the foot of a 200-metre cliff on Akpatok Island in the summer of 1993 and watching fledgling murre chicks leap from the nesting ledges, spread their stumpy wings, and glide steeply to the beach below where their parents waited to accompany them on foot to the water. It was an easy matter for the biologists to scoop up the chicks and weigh, measure, and band them before they reached the sea. An element of excitement was added by the presence of marauding Polar Bears, for whom the young birds appeared to be as tasty (and presumably as filling) as popcorn. On more than one occasion, bear and biologist met face-to-face, each having singled out the same chick as the next candidate for personal attention. On such occasions, the accepted protocol was for both parties to skid to a halt, turn, and run in opposite directions.[61]

Although the seabird program may have seemed at times like an exclusively Atlantic and Arctic preoccupation, others were working with seabirds in other parts of the country as well. In the Great Lakes, for example, D. V. (Chip) Weseloh, Christine A. Bishop, Pierre Mineau, and others focused on the effect of toxic contaminants on the reproductive success of gulls, terns, and cormorants (see Chapter 8).[62] Hans Blokpoel focused on documenting the distribution of colonial waterbirds in the Great Lakes, a long-term study that culminated in the publication of a five-volume *Atlas of Colonial Waterbirds Nesting on the Canadian Great Lakes, 1989–1991.*[63] His interest in terns and gulls also took him south, with technician Gaston D. Tessier, to Trinidad, Colombia, Venezuela, and Peru, supported by the CWS Latin American Program. That work, too, resulted in a number of publications.[64]

In comparison to the experience in eastern and northern Canada, the seabird program in the Pacific and Yukon Region took shape somewhat more gradually. In 1974, Kees Vermeer, who had been engaged in contaminant studies of fish-eating birds in the Prairie Region during the early 1970s, moved to British Columbia, where, in addition to his ongoing work on toxics, he turned his attention to Pacific seabirds and pelagic ecology and carried out pioneering research on several species. With a small research budget, Vermeer and his team began basic life history research on a wind-swept, treeless island about 40 kilometres northwest of Vancouver Island. He later extended these studies to Frederick and Langara islands in the Queen Charlotte Islands. Over a period of 20 years, he and his coworkers published some 55 papers on more than a dozen species, among them Rhinoceros Auklet, Tufted Puffin, Pelagic Cormorant, Mew Gull, and Black Oystercatcher. These were among the first studies of seabirds in British Columbia and provided the foundation for more elaborate ecological work in later years.[65]

About the same time, Gary W. Kaiser and Richard W. (Rick) McKelvey began aerial surveys to locate

Physical fitness, dependable safety equipment, and a good head for heights: the requirements for banding Thick-billed Murres and climbing mountains are virtually identical, as demonstrated in this instance by Tony Gaston at Digges Island, NWT (Photo credit: D. Noble).

wintering concentrations of seabirds and seaducks. These surveys were precursors to the work of Jean-Pierre Savard, whose primary research concentration was on the wintering ecology of seaducks, but who also studied alcids. He, Kaiser, Moira J. Lemon, Kathy Martin, and others became engrossed in distribution and habitat studies of the Marbled Murrelet, especially during the period leading up to and following the official listing of that tiny seabird as threatened.[66] At the time, no nests of the Marbled Murrelet had been found in Canada, but that very summer two naturalists, Irene Manley and John Kelson, discovered one in moss on the limb of a tree in the Carmanah Valley. Subsequent studies gave rise to the development of a national recovery plan for the species, in 1994.[67]

Another key participant in west coast seabird research was Tony Gaston, who, while retaining an active interest in Arctic murre colonies, moved west to add an extensive study of the Pacific Ancient Murrelet to his list of interests. In the Queen Charlotte Islands, he not only uncovered new information on this hitherto little-known seabird but also encouraged local residents to become interested in the birds so that there would be community support for ongoing monitoring and conservation once the field research was done.[68] His book on the Ancient Murrelet, published in 1992, was a highly readable natural history of the species.[69] Significantly, it was published commercially, CWS publication funds no longer being capable of supporting full-length monographs.

From 1981 to 1990, a total of 45 pelagic bird surveys were conducted along the British Columbia coast. Drawing heavily on the census methods that Dick Brown had developed in the North Atlantic in the early 1970s, K. H. (Ken) Morgan, Vermeer, and McKelvey gathered enough data to permit publication, in 1991, of the *Atlas of Pelagic Birds of Western Canada.*[70]

By the 1990s, seabird work, coordinated by a national Seabird Committee chaired by Gaston, was progressing at a variety of levels. Life histories of many individual species were relatively complete, and much of the emphasis had shifted to marine ecology and the value of seabirds as indicators of environmental health and quality. This was the case in Newfoundland, where Les Tuck had pioneered colonial seabird research for CWS. There, ongoing ecological studies at Cape St. Mary's, Witless Bay, Funk Island, and other important sites provided ample employment for Richard Elliot and later John Chardine.

An important addition to the national seabird program was the development of a functioning CWS Seabird Colony Registry. This was an idea rooted in the early 1970s, when Nettleship had outlined specifications for a seabird data storage and retrieval system.[71] Doug Gillespie had explored a similar concept for handling seaduck records during his time as resident CWS biologist in St. John's. The current database, however, was initiated in the Atlantic Region in 1987 to integrate existing seabird information from across Canada, make data readily accessible in the event of environmental emergencies, and assist in long-term strategic planning of marine conservation, coastal ecological action plans, and seabird studies.[72] As Canada's economic interests turn increasingly to overseas trade and exploitation of the resources of the continental shelf, the vital importance of tools such as this is likely to ensure a continuing role for the CWS seabird program.

Shorebirds

Hugh Boyd's transformation of ornithology at CWS did not stop with seabirds. Indeed, there were few, if any, aspects of the field that were not constructively influenced by this soft-spoken but stringent practitioner. He fostered a strong scientific approach, encouraging colleagues to publish, both in refereed journals and in the various CWS series — *Reports*, *Occasional Papers*, and *Progress Notes*. His long experience as editor of the British journal *Wildfowl* served him well as he aided them, and sometimes prodded them, to produce more and better reports. Many benefited from his rapid and careful review of manuscripts, and he was a driving force behind a broadening interchange of ideas and experiences between scientists in government and academic settings and between Canadian and "foreign" researchers.[73] Under his influence, CWS expanded its traditional partnership with the United States Fish and Wildlife Service to include closer ties with European and global agencies, such as the International Waterfowl Research Bureau (now Wetlands International). Reflecting on Boyd's contribution to CWS, Austin Reed observed:

> Although he occupied a managerial position for much of his pre-retirement career with CWS, Hugh's heart was clearly with the scientists, and more importantly with the waterfowl, seabirds, and shorebirds they studied. A new lease on life came after retirement as he returned under emeritus status to pursue his life-long love of observing the behaviour of wild geese. A full decade since retirement, each spring calls him back, like the geese themselves, to some remote part of the north.[74]

It was on a return visit to the United Kingdom in August 1970 that Boyd met a Canadian doctoral candidate at Cambridge named R. I. G. (Guy) Morrison. Morrison was an active participant in a shorebird research and banding team known as the Wash Wader Ringing Group. Soon after, he suggested to Morrison that, once his studies were complete, he consider applying for a new CWS position to set up a Canadian shorebird program.

Morrison arrived in 1973. Comparatively little shorebird work had been done in the Americas at that time. One of the first tasks was to identify the key areas where shorebirds bred, fed, rested, and wintered. A component of that work was the Maritimes Shorebird Survey, a volunteer monitoring program involving interested members of the public across Atlantic Canada. Since 1974, it has documented key shorebird locations and generated one of the few long-term data sets for tracing shorebird population and migration trends in North America over more than 20 years. A second initiative consisted of surveys of the mudflats and marshes lining the shores of Hudson Bay and James Bay between Churchill and Moosonee. This 1000-kilometre strip of coastal habitat between the muskeg and the sea serves as "a super highway for shorebirds,"[75] leading them southeast to the head of James Bay. From there, it is a relatively short flight to summer feeding grounds along the Bay of Fundy, where the birds gather to store energy for the long passage to South America.

For about 10 years during the 1970s and 1980s, CWS operated a banding station at James Bay where some 60 000 shorebirds were banded to provide information on dispersal and migration patterns. The banding crew, which operated mist nets around the clock in the long northern days, included CWS wildlife technician Barbara Campbell and an international team of volunteers from Canada, the United States, and Great Britain, as well as visitors from Suriname, Venezuela, and Trinidad. Marking the birds with coloured dyes was a feature of the program, enabling them to be spotted easily elsewhere. It caused a sensation at Johnson's Mills near Dorchester, New Brunswick, the first few times that a brilliant yellow bird was sighted among tens of thousands of drab, grey-brown Semipalmated Sandpipers. Many of the birds marked in James Bay were also seen in Suriname, on the northeast coast of South America.

A key participant in the banding project was Cheri Lynn Gratto-Trevor, then a student at Acadia University, who went on to gain a Ph.D. and become a research scientist with CWS at the Prairie Migratory Bird Research Centre in Saskatoon. Her work on the breeding ecology of shorebirds — especially Semipalmated Sandpipers[76] — at Churchill, Manitoba, has earned widespread international recognition.

Morrison pushed northward, banding in northeastern Ellesmere Island. Even before he had left England, he had been aware of suspicions that birds from this area migrated eastward to Europe, rather than to South America. Over the years, the migratory path became clear. After wintering in the United Kingdom, the birds stage in Iceland for about three weeks to fatten up before making the flight across the Greenland ice cap to Ellesmere. Research into the energetics of these migrants indicated that fuelling stops along the way are of vital importance if the birds are to arrive at their nesting grounds in good enough physical condition to breed successfully. The conclusion constituted a powerful argument in favour of protecting key areas along the entire length of the migration route of each species.

By the early 1980s, shorebird studies in the upper Bay of Fundy were providing corroboration of this logic. Peter W. Hicklin, a CWS biologist based in the Sackville, New Brunswick, office, spent whole seasons on the mudflats of Grande Anse and the Minas Basin, observing the foraging sites and invertebrate prey selection of the Semipalmated Sandpiper. It was evident that the two- to three-week sojourn of these southbound birds was as vital to their successful, nonstop migration to Suriname as the Iceland stopover was to northbound birds en route from Europe to Ellesmere Island.

Growing awareness of the significance of key locations such as these led Morrison to wonder if there were equally sensitive locations in the South American wintering grounds of Canadian breeding shorebirds. The recently initiated Latin American Program of CWS provided a context in which these questions could be asked. The Latin American Program was established in 1980 to promote the conservation of birds that migrate between Canada and Latin America. It was coordinated during its early years by Iola Price, and latterly by Colleen Hyslop.[77] Its objectives included the study of distribution and abundance of shared bird populations, the assessment of habitat requirements for migratory birds at stopover and wintering areas, and the mitigation of threats to birds and their habitats, especially when caused by human activity.[78]

The Latin American Program provided funding for Morrison and R. K. (Ken) Ross to map the wintering locations of Canadian summer breeding species. Between 1981 and 1986, they flew over nearly all areas of the South American coastline that had suitable habitat for shorebirds, counting close to three million shorebirds and identifying key wintering areas for several species. Their *Atlas of Nearctic Shorebirds on the Coast of South America* was published in 1989.[79]

The Latin American Program has funded many other shorebird-related activities. R. W. (Rob) Butler, a leading CWS shorebird specialist in the Pacific and Yukon Region, played a major role in research on the ecology of Western Sandpipers and their migration between the Fraser River Delta and wintering locations in Panama. André Bourget, Denis Lehoux, and Pierre Laporte conducted similar studies on shorebirds that winter in the Lesser Antilles. In 1983, Rick McKelvey and Barbara Campbell were invited to Brazil to train biologists in capture and banding techniques.

Peter Hicklin's initial work on shorebirds in the Bay of Fundy led to an exploration of the links between that location and wintering grounds in South America. In Suriname, in 1989, he and Dutch biologist Arie Spaans surveyed rice fields to assess their value as habitat and to determine what impact pesticides used to protect the rice crops might have on a variety of bird species.[80]

Many species of seabirds have been studied by CWS on the Great Lakes and at other inland locations. Here, Hans Blokpoel and Gaston Tessier weigh and measure a Ring-billed Gull near Hull, Quebec (Photo credit: N. Burgess).

One of the great benefits of the Latin American Program has been its value as a tool for networking with shorebird biologists and wildlife managers throughout North and South America. In May 1982, CWS organized the first Western Hemisphere waterfowl and waterbird symposium. This meeting in Edmonton, sponsored jointly with the International Waterfowl Research Bureau, brought waterbird specialists from South and Central America together with colleagues from North America for the first time. In 1985, at the time of the next board meeting of the International Waterfowl Research Bureau, a symposium on the conservation of Neotropical wetlands included discussion of a Canadian proposal for an international network of shorebird reserves to protect areas of critical habitat. Although the Western Hemisphere Shorebird Reserve Network (see also Chapter 10) operates as a nongovernment organization, it owes much of its genesis to the internationally directed CWS survey work. As of 1996, a total of 30 Western Hemisphere Shorebird Reserve Network sites had been established, three in Canada, 17 in the United States, two in Mexico, three in Suriname, two in Brazil, and three in Argentina. Collectively, they encompass millions of hectares of shorebird habitat and are used, at various times of the year, by more than 30 million birds.

From a single scientist working on shorebirds in 1973, the CWS commitment to shorebird studies has evolved to the point where there is at least one staff member committed to this field in each of the five regional offices and at headquarters. They meet regularly as the CWS Shorebird Committee, helping to coordinate their work across the country. They have produced an inventory of potential Western Hemisphere Shorebird Reserve Network sites[81] and an assessment of the status of shorebird populations occurring across Canada.[82]

Other Birds

Extending CWS activity to what he called "the twittering bird business" was a task that even Hugh Boyd approached with trepidation. It seemed like a long stretch for an organization whose public constituency for the previous 20 years had been largely composed of hunters to devote resources to "landbirds" — the warblers, woodpeckers, owls, sparrows, and other groups of birds that fell outside the mandate of formal conservation programs. Nonetheless, there was one candidate who might be interested in taking on the work.

Tony Erskine, although he was working exclusively with waterfowl at the time, had a longstanding interest in landbirds as well. As a graduate student at the University of British Columbia, he had been a participant in the British Columbia Nest Records program. Returning to the Maritimes with CWS in 1960, he had initiated the Maritime Nest Records Scheme. He later remarked that it might better have been called the A. J. Erskine Nest Records Scheme, at least during its first three years, when he was by far its most prolific contributor.

His interest did not pass unnoticed. In the winter of 1967–1968, David Munro, Hugh Boyd, and Graham Cooch met to discuss three concerns: how to deal with a proposal that amateur bird banding should be introduced at nature centres run by district school boards; how to deal with a growing collection of Canadian nest record cards without having to export them to the United States; and how to provide Canadian leadership for Breeding Bird Survey activities within Canada. Munro is credited with having said, "Why don't we get Tony Erskine in to do all three?"[83]

The position title was National Coordinator of Non-Game Birds, and it required Erskine to transfer from the Sackville office, which he liked, to Ottawa, which he viewed with a healthy Maritime skepticism. He stayed nearly nine years, from December 1968 to July 1977. As it turned out, the educational banding idea never expanded significantly. Conversion of data from the nest records scheme into a computerized form that could be used in Canada was an ongoing, but not overly demanding, responsibility. The major task turned out to be coordination of the Breeding Bird Survey, a volunteer-based project that had originated in the United States. Each participant in the annual survey was assigned a predetermined 40-kilometre route to be travelled on a morning at the height of the nesting season. In the course of the trip, each volunteer would make 50 stops at 0.8-kilometre intervals, recording the names and numbers of birds seen or heard during a three-minute period. Once survey routes were in operation all across the continent, trends in species range, abundance, and diversity could be tracked with unprecedented accuracy.

Under Erskine's leadership, the scale and extent of the Breeding Bird Survey in Canada grew rapidly, from 33 routes in the Maritimes (and three in Quebec) in 1966 to 148 across the country by 1969. At the end of the first decade, the number of routes surveyed had risen to 249. Ensuring that each route was covered annually, using a consistent methodology, required careful coordination of volunteer observers. In a 10-year summary of the survey, published in 1978, Erskine took special pains to express his appreciation to long-time, regional volunteer coordinators.[84]

A related research project kept Erskine in the field himself for part of each year during this period. In the summer of 1968, in preparation for his new duties, he had spent several weeks working on census plots to see if a more efficient method of monitoring landbirds than the line transect approach then in use could be devised. In the course of this investigation, the idea occurred to him that doing comparable surveys of boreal habitat in several regions across the country could produce a useful contribution to the state of knowledge about Canadian landbirds. The project was well-suited to Erskine's own interests and had the added advantage of not requiring either a big budget or a large team of people. Year by year the data accumulated until, in the summer of 1977, *Birds in Boreal Canada* was published as the first major CWS report on landbirds.[85]

Although Erskine sustained an active interest in the Breeding Bird Survey after his return to the Maritimes as regional Chief of Migratory Birds in 1977, others began to assume the coordinating and reporting responsibilities.[86] Connie Downes became the Breeding Bird Survey National Coordinator in 1993, working at the National Wildlife Research Centre in Hull. The real success of the venture over more than 30 years, however, has depended on the readiness of volunteers (now numbering in the hundreds) to rise before dawn and travel their preset courses. In 1995, the 30th annual survey included a record 432 routes, with significant coverage in every province and territory except Newfoundland (two routes) and the Northwest Territories (one route). With public interest in bird observation at an all-time high, organizers project that the number could surpass 600 by the year 2000.[87]

The Breeding Bird Survey itself has been instrumental in raising general public awareness of the importance of bird studies to such a level. Embraced by CWS and by Canadian naturalists, it helped lay the foundations for a wide range of other landbird studies. Survey veterans, for example, were an experienced mainstay of the corps of volunteer observers who gathered data for the breeding bird atlases published for most provinces of Canada since the mid-1980s. CWS stalwarts such as Tony Erskine[88] in the Maritimes, Jean Gauthier and Yves Aubry[89] in Quebec, Steven C. (Steve) Curtis in Ontario, and Geoffrey (Geoff) Holroyd in Alberta played lead roles in these ambitious partnerships, securing funding and collaborating closely with their counterparts in provincial government agencies and universities, and with thousands of amateur and professional ornithologists.

The Breeding Bird Survey and the breeding bird atlas projects were not the only surveys of landbird populations in which CWS played an important role. Starting with a pilot study in 1987, CWS biologist Dan Welsh of the Ontario regional staff initiated a volunteer-based Forest Bird Monitoring Program in association with the Ontario Ministry of Natural Resources. Focusing on old-growth pine forest in the Temagami district, the program used a standardized method similar to that of the Breeding Bird Survey, although, since the survey areas were inaccessible by road, participants travelled on foot, making a prescribed number of 10-minute stops. When the Forest Bird Monitoring Program was first instituted, it involved some 30 participants.[90] A decade later, 150 volunteers were surveying birds in forest habitat each spring, under the coordination of Mike Cadman of CWS.

The accumulation of data on landbirds, abetted by a growing public interest in birds and the environment, has helped determine CWS priorities in nongame bird conservation. In 1991, Steve Wendt and Colleen Hyslop became involved in setting up a songbird (subsequently landbird) committee within the Wildlife Service. Breeding Bird Survey data and other continental trends in bird abundance and distribution were demonstrating long-term declines in a number of species of landbirds. At a joint meeting of Canadian and American representatives attended by Wendt, a collaborative program known as "Partners in Flight" was established to enquire into the reasons for these trends and to take steps to ensure the viability of native landbirds across their range of habitats.

Thousands of shorebirds have been banded over the years at the CWS station at Johnson's Mills, near Dorchester Cape, New Brunswick. Here, during the 1987 summer study, student assistant Donna Burris releases a Semipalmated Sandpiper (Photo credit: CWS).

In Canada, one of the first steps in the realization of this goal was to bring together a broad range of specialists to develop a *Framework for Landbird Conservation in Canada*.[91] In all, it involved seven federal departments and agencies, provincial wildlife, agriculture, and forestry departments, 11 nongovernment environmental organizations, as well as aboriginal communities, academics, and private companies. The consultation process and the resulting document, both coordinated by Judith Kennedy at CWS headquarters, provided a base from which CWS and other core Canadian members of "Partners in Flight"[92] would develop programs to monitor, research, and apply landbird conservation strategies, region by region and ecosystem by ecosystem, across the country.[93] Subsequently, Kennedy and Hyslop developed an annual newsletter, *Bird Trends*, to keep participants and partners in the program informed.

Research Renewed

In 1991, with the introduction of the National Wildlife Strategy under Canada's Green Plan, still more opportunities emerged for ornithological research. Three initiatives merit particular mention in relation to the study of landbirds and of birds in general. One was the provision of funding to support coordination of volunteer-based monitoring projects such as the Breeding Bird Survey and Forest Bird Monitoring Program. Half a dozen positions were either created or adapted to encompass this growing area of responsibility in response to recommendations contained in documents such as the Wildlife Policy for Canada and in anticipation of the signing of the Convention on Biological Diversity.[94] The Canadian Landbird Monitoring Strategy, compiled by Connie Downes in 1994, summarized a variety of data-gathering activities aimed at determining the abundance (Breeding Bird Survey, Canadian Migration Monitoring Network, Hawkwatching), distribution (breeding bird atlases, Christmas Bird Counts, birdlist surveys), habitat associations (Forest Bird Monitoring Program), and productivity and survivorship of birds.[95]

A second set of positions, introduced or altered under the Green Plan and related to work with landbirds, focused on the development of integrated wildlife research and monitoring programs in forest ecosystems. It reflected a philosophic shift in forestry, away from an exclusive emphasis on wood and wood fibre production and towards acknowledgment of diversified, multipurpose ecosystem management.[96]

The third Green Plan initiative with significant impact on ornithological research was the provision of funds for a network of wildlife ecology research centres at Canadian universities. The idea, patterned on cooperative research units in the United States, had evoked keen interest at a Colloquium on Wildlife Conservation[97] in May 1986. Following the Colloquium, a task force was established to explore the topics that had been aired. One member of that task force, George W. Scotter of CWS, examined the cooperative research concept with colleagues across the country and prepared a proposal.[98] Five years later, a modified version was introduced.

The availability of Green Plan funding for the purpose of promoting research partnerships met varied responses from region to region. Arthur M. (Art) Martell, then CWS Regional Director in British Columbia, had a strong background as a research scientist himself. Having already pressed for identification of the Pacific and Yukon Regional Office at Delta as the Pacific Wildlife Research Centre, he seized the opportunity to implement Scotter's proposal and moved swiftly to establish the CWS/Natural Sciences and Engineering Research Council of Canada Chair of Wildlife Ecology at Simon Fraser University. In 1993, Fred Cooke inaugurated the program, leaving Queen's University and accepting appointment to the new position.

Not unexpectedly, Cooke's focus was largely on waterfowl, seabirds, shorebirds, and wetland and coastal ecology. Martell sought to complement this concentration by enlisting Kathy Martin, a CWS research scientist with a strong interest in forest birds and forest ecology, in a second university partnership, securing her a part-time cross-appointment to the applied conservation biology program in the Faculty of Forestry at the University of British Columbia.

The other eager response to the Green Plan funding for wildlife research came from the Atlantic Region. There, faced with the political sensitivity of dealing with four provinces, Regional Director George Finney negotiated the establishment of an Atlantic Cooperative Wildlife Research Network. CWS veteran Tony Diamond accepted the Senior Chair at the University of New Brunswick, while Associate Chairs at Memorial University of Newfoundland and Acadia University in Nova Scotia were occupied by ornithologists Ian L. Jones and Philip D. Taylor, respectively.

Other regions responded less urgently. In the west, the Prairie Migratory Bird Research Centre had over a quarter century of accomplishments behind it. The Ontario and Quebec Regions had other research priorities and other ways of funding them. Still, by helping to implant new research partnerships on both coasts, CWS succeeded in using the short-lived Green Plan effectively to enhance the quality and quantity of Canadian ornithological research.

Notes

1. A. G. Loughrey, "A draft federal wildlife policy for Canada" in *Transactions of the 44th Federal–Provincial Wildlife Conference*, 24–27 June 1980, Ottawa (Ottawa: Canadian Wildlife Service, 1980), page 32.
2. Henri Ouellet, "Ornithology at Canada's National Museum" in *Contributions to the History of North American Ornithology* (Cambridge, Massachusetts: Memoirs of the Nuttall Ornithological Club Number 12, 1995), page 308.
3. Ouellet, "Ornithology at Canada's National Museum," page 314. (See note 2)
4. David A. Munro, "Tribute to Hoyes Lloyd, 1888– 1978," *The Canadian Field-Naturalist* 93: 331–336 (1979).
5. Robie W. Tufts, *The Birds of Nova Scotia* (Halifax: Nova Scotia Museum, 1962; 2nd edition published 1973).
6. W. E. Stevens and G. W. Scotter, "Joseph Dewey Soper, 1893–1982," *The Canadian Field-Naturalist* 97: 350–353 (1983).

Nev Garrity plays recorded songs and call notes of Bicknell's Thrush in an attempt to locate individual birds in Cape Breton, Nova Scotia. This research project under biologist Dan Busby helped delineate the distribution and abundance of the newly recognized native landbird species in the Maritimes (Photo credit: D. Busby).

7. J. Dewey Soper to Percy A. Taverner, 18 July 1929; reproduced in John L. Cranmer-Byng, "A Life with Birds: Percy A. Taverner," *The Canadian Field-Naturalist* 110(1): 150 (1996).
8. George W. Scotter, "Publications of J. Dewey Soper," *The Canadian Field-Naturalist* 97: 353–355 (1983).
9. V. E. F. Solman, "Harrison Flint Lewis, 1893–1974," *The Canadian Field-Naturalist* 88: 509 (1974).
10. F. G. Cooch, personal communication, interviewed March 1997.
11. A. J. Erskine, personal communication, interviewed February 1997.
12. D. Munro, personal communication, interviewed at Sidney, British Columbia, 30 November 1996.
13. G. F. Boyer, *Wildlife Conditions in the Maritime Provinces* (Sackville, New Brunswick: Dominion Wildlife Service internal report, 1947).
14. J. Dewey Soper, Wildlife Management Bulletins Series 1, Numbers 3, 5, and 7; Series 2, Numbers 2, 3, 4, and 6 (Ottawa: Canadian Wildlife Service, 1952, 1953).
15. J. A. Munro, *The American Merganser in British Columbia and Its Relation to Fish Populations* (Ottawa: Biological Board of Canada, Fisheries Research Board Bulletin 55, 1937).
16. Erskine, personal communication. (See note 11)
17. A. J. Erskine, *Populations, Movements and Seasonal Distribution of Mergansers in Northern Cape Breton Island* (Ottawa: Canadian Wildlife Service Report Series, Number 17, 1972).
18. R. G. B. Brown, *Bird Damage to Fruit Crops in the Niagara Peninsula* (Ottawa: Canadian Wildlife Service Report Series, Number 27, 1974).
19. André Bourget, personal communication, interviewed 25 March 1997.
20. H. Rueggeberg and J. Booth, *Marine Birds and Aquaculture in British Columbia: Preventing Predation by Scoters on a West Coast Mussel Farm* (Vancouver: Canadian Wildlife Service Pacific and Yukon Region, Technical Report Series, Number 74, 1989).
21. J. L. Parsons, E. J. Hiscock, and P. W. Hicklin, *Reduction of Losses of Cultured Mussels to Sea Ducks* (Canada–Nova Scotia Regional Development Agreement, Report Number 17, 1990).
22. J. A. Burnett, W. Lidster, P. Ryan, and C. Baldwin, *Saving Cultured Mussels and Waterfowl in Newfoundland* (Sackville, New Brunswick: Canadian Wildlife Service Atlantic Region, Summary report, 1994).
23. Transport Canada, *Airport Wildlife Management: 50 Years of Canadian Bird Strikes* (Ottawa: Bulletin Number 16, 1995).
24. When the original committee was replaced by the Bird Strike Committee Canada, its focus shifted away from research and towards practical implementation of control programs, but Vic Solman's pioneering work to make flying safer for both people and birds was not forgotten. In 1977, he received the Gold Medal of the Professional Institute of the Public Service of Canada, and in 1986, he was presented with a special award by the European Bird Strike Committee. He was also very pleased to be invited, in 1992, to address the inaugural meeting of the Bird Strike Committee USA on his 50 years of study of Canadian bird strikes.
25. Hans Blokpoel, *Bird Hazards to Aircraft* (Toronto: Clarke, Irwin & Company Ltd., 1976).
26. H. Blokpoel and G. D. Tessier, *The Ring-billed Gull in Ontario: A Review of a New Problem Species* (Ottawa: Canadian Wildlife Service Occasional Paper Number 57, 1986).
27. David A. Munro and J. Bernard Gollop, "Canada's place in flyway management," *North American Wildlife Conference* 230: 118–125 (1955).
28. Denis A. Benson, *Use of Aerial Surveys by the Canadian Wildlife Service* (Ottawa: Department of Northern Affairs and National Resources, Canadian Wildlife Service Occasional Paper Number 3, 1962).

29. cf. Canada, Department of Indian and Northern Affairs, *Saskatoon Wetlands Seminar* (Ottawa: Canadian Wildlife Service Report Series, Number 6, 1969).
30. Indian and Northern Affairs, *Saskatoon Wetlands Seminar*, page 2. (See note 29)
31. F. G. Cooch, "Waterfowl-production habitat requirements" in Canada, Department of Indian and Northern Affairs, *Saskatoon Wetlands Seminar* (Ottawa: Canadian Wildlife Service Report Series, Number 6, 1969), pages 5–10.
32. L. Lemieux and G. Moisan, "The migration, mortality rate and recovery rate of the Quebec Black Duck" in *Transactions of the Northeast Wildlife Conference* 10: 124–148 (1959).
33. D. Lehoux, A. Bourget, P. Dupuis, and J. Rosa, *La sauvagine dans le système du Saint-Laurent (fleuve, estuaire, golfe)* (Environment Canada, Canadian Wildlife Service Quebec Region, unpublished report, 1985).
34. D. J. Nakashima, "Inuit knowledge of the ecology of the Common Eider in northern Quebec" in A. Reed (editor), *Eider Ducks in Canada* (Ottawa: Environment Canada, Canadian Wildlife Service Report Series, Number 47, 1986).
35. A. Reed, Y. Aubry, and E. Reed, "Surf Scoter (*Melanitta perspicillata*) nesting in southern Québec," *The Canadian Field-Naturalist* 108(3): 364–365 (1994).
36. A. J. Erskine, *Buffleheads* (Ottawa: Environment Canada, Canadian Wildlife Service Monograph Series, Number 4, 1972).
37. e.g., J.-P. L. Savard, "Territorial behaviour of Common Goldeneye, Barrow's Goldeneye, and Bufflehead in areas of sympatry," *Ornis Scandinavica*, 15: 211–216 (1984).
38. R. I. Goudie, "Historical status of Harlequin Ducks wintering in eastern North America — a reappraisal," *Wilson Bulletin* 101: 112–114 (1989).
39. J.-P. L. Savard and P. Lamothe, "Distribution, abundance, and aspects of the breeding ecology of Black Scoters, *Melanitta nigra*, and Surf Scoters, *M. perspicillata*, in northern Quebec," *The Canadian Field-Naturalist* 105: 488–496 (1991).
40. Erskine, personal communication. (See note 11)
41. Erskine, personal communication. (See note 11)
42. Barbara Campbell, personal communication, interviewed at Ottawa, 26 November 1996.
43. G. Finney, personal communication, Sackville, New Brunswick, 12 July 1998.
44. H. Boyd, personal communication, interviewed at Ottawa, 27 November 1996.
45. G. Chapdelaine, "Fourteenth census of seabird populations in the sanctuaries of the North Shore of the Gulf of St. Lawrence, 1993," *The Canadian Field-Naturalist* 109(2): 220–226 (1995).
46. David Nettleship, personal communication, interviewed at Dartmouth, Nova Scotia, 12 March 1997.
47. Leslie M. Tuck, *The Murres: Their Distribution, Populations, and Ecology* (Ottawa: Canadian Wildlife Service Monograph Series, Number 1, 1961).
48. David N. Nettleship, "Hugh James Boyd: the 1997 Doris Huestis Speirs Award for outstanding contributions to Canadian ornithology," *Picoides* 10(2): 19 (1997).
49. Boyd, personal communication. (See note 44)
50. D. N. Nettleship and T. R. Birkhead (editors), *The Atlantic Alcidae* (London: Academic Press, Harcourt Brace, Jovanovitch, 1985).
51. R. G. B. Brown, D. N. Nettleship, P. Germain, C. E. Tull, and T. Davis, *Atlas of Eastern Canadian Seabirds* (Ottawa: Canadian Wildlife Service, 1975).
52. R. G. B. Brown, *Revised Atlas of Eastern Canadian Seabirds. 1. Shipboard Surveys* (Ottawa: Canadian Wildlife Service, 1986).
53. R. G. B. Brown, D. I. Gillespie, A. R. Lock, P. A. Pearce, and G. H. Watson, "Bird mortality from oil slicks off eastern Canada, February–April 1970," *The Canadian Field-Naturalist* 87: 225–234 (1973).
54. R. G. B. Brown, *The Voyage of the Iceberg: The Story of the Iceberg that Sank the Titanic* (Toronto: James Lorimer & Company, 1983).
55. A. R. Lock, personal communication, interviewed at Sackville, New Brunswick, September 1997.
56. A. R. Lock, R. G. B. Brown, and S. H. Gerriets, *Gazetteer of Marine Birds in Atlantic Canada* (Environment Canada, Canadian Wildlife Service Atlantic Region, 1994).
57. Nettleship, personal communication. (See note 46)
58. A. J. Gaston and D. N. Nettleship, *The Thick-billed Murres of Prince Leopold Island — A Study of the Breeding Ecology of a Colonial High Arctic Seabird* (Ottawa: Canadian Wildlife Service Monograph Series, Number 6, 1981).
59. D. G. Noble, A. J. Gaston, and R. D. Elliot, "Preliminary estimates of survivorship and recruitment for Thick-billed Murres at Coats Island" in A. J. Gaston and R. D. Elliot (editors), *Studies of High-latitude Seabirds. 2. Conservation Biology of Thick-billed Murres in the Northwest Atlantic* (Ottawa: Canadian Wildlife Service Occasional Paper Number 69, 1991), pages 45–51.
60. G. Finney, personal communication. (See note 43)
61. G. Chapdelaine, personal communication, Quebec City, March 1997.
62. e.g., C. A. Bishop, D. V. (Chip) Weseloh, Neil M. Burgess, John Struger, Ross J. Norstrom, Richard Turle, and Karen Logan, *An Atlas of Contaminants in Eggs of Fish-eating Colonial Birds of the Great Lakes (1970–1988). Volume I: Accounts by Species and Locations* (Canadian Wildlife Service Technical Report Series, Number 152, 1992).
63. e.g., H. Blokpoel and G. Tessier, *Atlas of Colonial Waterbirds Nesting on the Canadian Great Lakes, 1989–1991. Part 1: Cormorants, Gulls and Island-nesting Terns on Lake Superior in 1989* (Canadian Wildlife Service Technical Report Series, Number 181, 1993).
64. e.g., Hans Blokpoel, Ralph D. Morris, and Gaston D. Tessier, "Field investigations of the biology of common terns wintering in Trinidad," *Journal of Field Ornithology* 55(4): 424–434 (1984); and H. Blokpoel, D. C. Boersma, R. A. Hughes, and G. D. Tessier, "Field observations of the biology of Common Terns and Elegant Terns wintering in Peru," *Colonial Waterbirds* 12(1): 90–96 (1989).
65. e.g., K. Vermeer, R. W. Butler, and K. H. Morgan, *The Ecology, Status, and Conservation of Marine and Shoreline Birds on the West Coast of Vancouver Island* (Ottawa: Canadian Wildlife Service Occasional Paper Number 75, 1992).

66. J.-P. L. Savard and Moira J. Lemon, *Geographic Distribution of the Marbled Murrelet on Vancouver Island at Inland Sites during the 1991 Breeding Season* (Canadian Wildlife Service Technical Report Series, Number 189, 1994). See also G. W. Kaiser, T. E. Mahon, and M. D. Fawcett, *Studies of Marbled Murrelets in Marine Habitats during 1990* (Delta, British Columbia: Pacific and Yukon Region, Canadian Wildlife Service Technical Report Series, Number 131, 1991).
67. G. W. Kaiser, H. J. Barclay, A. E. Burger, D. Kangasniemi, D. J. Lindsay, W. T. Munro, W. R. Pollard, R. Redhead, J. Rice, and D. Seip, *The National Recovery Plan for the Marbled Murrelet* (Ottawa: Recovery of Nationally Endangered Wildlife Committee Report Number 8, 1994).
68. An interesting footnote to the Ancient Murrelet story emerged in 1995, when CWS undertook to protect nests of the species on Langara Island from the depredations of rats. Gary Kaiser worked with New Zealand biologist Rowley Taylor to devise an eradication scheme that took less than three weeks to eliminate most of the predators. A brief follow-up campaign extirpated rats from the island. cf. G. W. Kaiser, R. H. Taylor, P. D. Buck, J. E. Elliott, G. R. Howald, and M. C. Drever, *The Langara Island Seabird Habitat Recovery Project: Eradication of Norway Rats 1993–1997* (Delta, British Columbia: Pacific and Yukon Region, Canadian Wildlife Service Technical Report Series, Number 304, 1997).
69. A. J. Gaston, *The Ancient Murrelet: A Natural History in the Queen Charlotte Islands* (London: T. & A.D. Poyser, 1992).
70. K. H. Morgan, K. Vermeer, and R. W. McKelvey, *Atlas of Pelagic Birds of Western Canada* (Ottawa: Environment Canada, Canadian Wildlife Service Occasional Paper Number 72, 1991).
71. D. N. Nettleship, *Census Techniques for Seabirds of Arctic and Eastern Canada* (Ottawa: Canadian Wildlife Service Occasional Paper Number 25, 1976).
72. D. N. Nettleship, "The CWS Seabird Colony Registry: access to seabird colony data using a computerized storage-retrieval system," *Colonial Waterbird Society Bulletin* 16(2): 41–44 (1992).
73. Following his retirement, Hugh Boyd has continued to influence the quality and diversity of ornithological research and reporting at CWS. His contributions to the field have been recognized by a number of prestigious awards, including, in 1996, the first Peter Scott Medal from the Wildfowl and Wetlands Trust in England for "his relentless pursuit of scientific evidence and promotion of its use in policy-making on conservation on two continents"; in 1997, the Doris Huestis Speirs Award from the Canadian Society of Ornithologists, for Outstanding Contributions to Canadian Ornithology; and in 1997, one of only 20 Honorary Memberships in the British Ornithologists' Union for "lifetime contributions to ornithology."
74. Austin Reed, personal communication, March 1998.
75. R. I. G. Morrison, personal communication, interviewed at Hull, Quebec, 5 December 1996.
76. cf. C. L. Gratto-Trevor, "The Semipalmated Sandpiper" in A. Pool, P. Stettenheim, and F. Gill (editors), *The Birds of North America*, Number 1 (Philadelphia: American Ornithologists' Union; Washington, D.C.: Academy of Natural Sciences, 1993).
77. C. Hyslop and I. Davidson, *CWS Latin American Program: The First Thirteen years 1980–1993* (Ottawa: Environment Canada, 1994).
78. Canadian Wildlife Service, *Shorebirds We Share: Canadian Wildlife Service Latin American Program* (Ottawa: Environment Canada, 1996).
79. R. I. G. Morrison and R. K. Ross, *Atlas of Nearctic Shorebirds on the Coast of South America.* 2 volumes (Ottawa: Canadian Wildlife Service Special Publication, 1989).
80. P. W. Hicklin and A. L. Spaans, *The Birds of the SML Rice Fields in Suriname: Species Composition, Numbers, and Toxic Chemical Threats* (Sackville, New Brunswick: Canadian Wildlife Service Technical Report Series, Number 174, 1992). Kees Vermeer had earlier done similar work in Suriname.
81. R. I. G. Morrison, R. W. Butler, G. W. Beyersbergen, H. L. Dickson, A. Bourget, P. W. Hicklin, J. P. Goossen, R. K. Ross, and C. L. Gratto-Trevor, *Potential Western Hemisphere Shorebird Reserve Network Sites for Migrant Shorebirds in Canada*, second edition (Ottawa: Canadian Wildlife Service Technical Report Series, Number 227, 1995).
82. R. I. G. Morrison, A. Bourget, R. Butler, H. L. Dickson, C. L. Gratto-Trevor, P. Hicklin, C. Hyslop, and R. K. Ross, *A Preliminary Assessment of the Status of Shorebird Populations in Canada* (Ottawa: Canadian Wildlife Service Progress Notes Number 208, 1994).
83. Erskine, personal communication. (See note 11)
84. A. J. Erskine, *The First Ten Years of the Cooperative Breeding Bird Survey in Canada* (Environment Canada, Canadian Wildlife Service Report Series, Number 42, 1978). Long-time regional volunteer coordinators whom he acknowledged were David Christie (Maritimes), Martin Edwards and Murray Speirs (Ontario), Herbert Copland (Manitoba), Jack Park (Alberta), and Wayne Neily (Yukon).
85. A. J. Erskine, *Birds in Boreal Canada: Communities, Densities and Adaptations* (Ottawa: Canadian Wildlife Service Report Series, Number 41, 1977).
86. The changing authorship of annual *Progress Notes* on the survey provides at least a partial "Who's Who" of key participants over the years: George Finney, Kathryn Freemark, C. R. Cooper, E. Silieff, Brian Collins, John Chardine, Ellen Hayakawa, and Connie Downes.
87. C. Downes (editor), *BBS Canada: A Newsletter for Cooperators in the Breeding Bird Survey of Canada* (Ottawa: Canadian Wildlife Service, National Wildlife Research Centre, Winter 1997).
88. A. J. Erskine, *Atlas of Breeding Birds of the Maritime Provinces* (Halifax: Nimbus Publishing and the Nova Scotia Museum, 1992).
89. Jean Gauthier and Yves Aubry (editors), *The Breeding Birds of Quebec: Atlas of the Breeding Birds of Southern Quebec* (Montreal: Association québécoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, and Canadian Wildlife Service, Quebec Region, 1996).
90. Canadian Wildlife Service, Ontario Region, *Annual Review: 1989–1990* (Ottawa: Environment Canada, 1990), pages 9–10.

91. A Landbird Conservation Working Group, *Framework for Landbird Conservation in Canada* (Hull, Quebec: Partners in Flight – Canada, 1996).
92. Partners in Flight core members are CWS, Bird Studies Canada, the Canadian Wildlife Federation, the Canadian Pulp and Paper Association, the Canadian Nature Federation, the Society of Canadian Ornithologists, and Wildlife Habitat Canada.
93. Key CWS participants in the development of the landbird conservation initiative have included Peter Blancher, Dan Busby, Mike Cadman, Tony Diamond, Loney Dickson, Erica Dunn, Jean Gauthier, Judith Kennedy, Jean-Pierre Savard, Dan Welsh, and Steve Wendt.
94. Personnel either hired or reassigned to this work included Dan Busby (Atlantic), Mike Cadman (Ontario), Brenda Dale (Prairies), Rhonda Millikin (British Columbia), Wendy Nixon (Yukon), and Connie Downes at the National Wildlife Research Centre at headquarters.
95. Migratory Bird Populations Division, *Canadian Landbird Monitoring Strategy* (Hull, Quebec: Canadian Wildlife Service, National Wildlife Research Centre, 1994).
96. This Green Plan initiative helped fund the work of Kathy Martin in British Columbia, Keith Hobson in the Prairies, Dan Welsh in Ontario, Jean-Pierre Savard in Quebec, Gerry Parker in Atlantic Canada, and Erica Dunn at the National Wildlife Research Centre.
97. cf. Robert A. Jantzen, "Background comments on cooperative research units" in *Colloquium on Wildlife Conservation in Canada*, Ottawa, 7–8 May 1986 (Ottawa: Environment Canada, 1986).
98. G. W. Scotter, "A proposal for cooperative wildlife research institutes at Canadian universities" in *Report to Wildlife Ministers from the Wildlife Conservation Colloquium Task Force* (Ottawa: Minister of the Environment, Appendix Report 5, 1987), pages 38–65.

1957–1962: A Broader Mission

In April 1957, Bill Mair began his sixth year as Chief of CWS. The following November, the Wildlife Service entered its second decade. Under Mair's effective leadership, CWS had gained a real sense of confidence in its mission. Accounts of CWS activities in the annual reports of the Department of Northern Affairs and National Resources between 1957 and 1962 might lead one to conclude that the period of development was over, that the agency had settled down to discharge routine tasks. Each year's official record noted succinctly that waterfowl, snipe, and woodcock populations had been surveyed; that studies had been conducted in the Prairies on crop damage by waterfowl; that field research had been carried out on the distribution, abundance, and habitat of various mammals and migratory birds; that sport fishing had been enhanced in a number of lakes; and that the regulations of the Migratory Birds Convention Act had been enforced with the collaboration of the RCMP.

Like the visible portion of an iceberg, those minimal notes barely hinted at what lay beneath the surface. Alongside other federal scientific agencies such as the National Museum and the Geological Survey of Canada, CWS was still deeply immersed in the enormous task of discovering and describing the natural resources of the second largest country in the world. Little by little, blanks on the biophysical map were filled in as biologist-explorers returned from field expeditions to report on a multiplicity of interests: the abundance of colonial seabirds in bird sanctuaries around the Gulf of St. Lawrence; the breeding range of the Greater Snow Goose; the condition of Muskox habitat on the Thelon River; the population density of Thick-billed Murres on Bylot Island; the potential of mountain lakes for trout fishing; or the impact of predation by Wolves on Barren-ground Caribou.

Statistics told part of the tale. The number of Migratory Bird Sanctuaries in Canada increased from 95 in 1957 to 108 in 1962; their combined area grew from 13 000 to 103 000 square kilometres over the same period.[1] CWS continued to coordinate bird banding activities across the country and to receive and process between 122 000 and 148 000 banding records a year. Many other significant advances, less readily quantifiable, were evident in the growing degree of ecological sophistication with which wildlife topics were discussed. The minutes of successive Federal–Provincial Wildlife Conferences contain an excellent chronicle of this process.

The questions posed at these conferences in the late 1950s reveal the early evolution of many wildlife management issues that remain highly relevant to the present day. How could hunting regulations be adapted to accommodate new technologies? Should CWS play a role in controlling pollution of inland and coastal waters? What were the rights and responsibilities of aboriginal people in the management of wildlife resources? What was the best way to govern the import and export of wildlife and wildlife products? Should Canada have a National Wildlife Act?

A decade earlier, in defining the mandate of the new agency, federal officials had downplayed the degree to which CWS should become involved in wildlife research that was not directly related to its own regulatory and management functions. By the summer of 1957, however, provincial delegates to the 21st Federal–Provincial Wildlife Conference

Even with the addition of air transport, the field resources available to CWS were seldom proportional to the tasks undertaken. The vastness of the land is dramatically illustrated in this 1961 photograph of a Piper Cub in the air over the Hazen Lake region of Ellesmere Island. Note the edge of the ice cap in the background (Photo credit: D. Thomas).

were pressing for formal acknowledgment that the research role of the federal agency should be interpreted much more broadly. Resolution #3 "repeated the request of previous conferences that the Canadian Wildlife Service should be empowered to assist provinces in wildlife research."[2] The following, much abridged minutes of the discussion surrounding this resolution at the 22nd Conference a year later give some indication of the multiple agendas represented around the table:

Mr. Mason [C. A. Mason, Director of Game, Nova Scotia] said that in the Maritimes...many people depend on tourists and their hunting and fishing, but are not able to carry on biological programmes as they are hindered by salary problems....He felt there should be some federal assistance and he could see no reason why the British North America Act could not be amended for the raising of federal funds by similar methods as used in the United States.

Mr. Parker [L. A. Parker, Assistant Director, United States Bureau of Sports Fisheries and Wildlife] gave a brief outline of the situation in the U.S. The Fish and Wildlife Service resulted from an act authorizing the Agricultural Division to study birds and bird habits [sic] in 1885. A Federal Excise Tax which was to have been rescinded was continued and the funds received from it were earmarked for the program on wildlife....

Hon. Mr. Levy [Minister of Lands and Forests, Nova Scotia] suggested that personnel should be made available rather than funds....

Mr. Butler [F. R. Butler, Game Commissioner, British Columbia] felt that the Federal Government is morally obligated to assist the provinces. He indicated that the Provincial Government expended money on duck habitat and that the Federal Government should do likewise. He felt that all provincial representatives should submit their ideas of the amount of money required to Mr. Mair....

Mr. Malaher [G. W. Malaher, Director of Game and Fisheries, Manitoba] said that the same problems were to be found in forestry and fisheries. He wondered if some action would be taken if the provinces indicated their interest in a Wildlife Act.

...He asked if it would be helpful if the provinces were to bring forward the matter of a Wildlife Act....

Dr. Harkness [W. J. K. Harkness, Chief, Fish and Wildlife Division, Ontario] felt that...some guide should be given so that there would be uniformity in the provinces' requests.

The Chairman [W. W. Mair, Chief, CWS] asked what type of wildlife research was most necessary. He suggested that the provinces cooperate in their request, emphasizing the areas where the need is greatest. He felt that he had a fair idea of what was required but he could not prepare a brief until he had more specific details...from each of the provincial officials.[3]

The dialogue is interesting not only as an example of the variety of positions and styles that could surface at federal–provincial gatherings, but also as a demonstration of Mair's skill at building consensus. He employed a similar technique at the 23rd

Conference, in 1959, to channel a discussion on the definition of "wilderness areas" into constructive action. Wondering aloud about whether participants shared a common objective or were talking about two concepts — small, tightly restricted ecological reserves and larger wilderness recreation areas — he thanked them for their input and proposed to circulate a paper when time permitted.[4]

With regard to the question of the research role of CWS, it was not Mair but Assistant Chief Vic Solman who addressed the 1959 conference, delivering a paper in which he noted:

> Canada is emerging from an era of exploitive use of the wildlife resource, which was an essential part of the opening of the country. The demand in future will be increasingly for recreational uses that require careful management of land use and productivity.[5]

CWS research, he said, fell into three broad categories:

- fundamental research, aimed at deriving new knowledge;
- applied research, aimed at solving wildlife management problems using known data; and
- exploratory research, aimed at discovering and describing Canada's biological resources.

He summarized the objectives of the federal wildlife research policy in 10 points that outlined a mission for the Wildlife Service that was at once more explicit and far more extensive than that which R. A. Gibson had defined for Harrison Lewis in 1947:

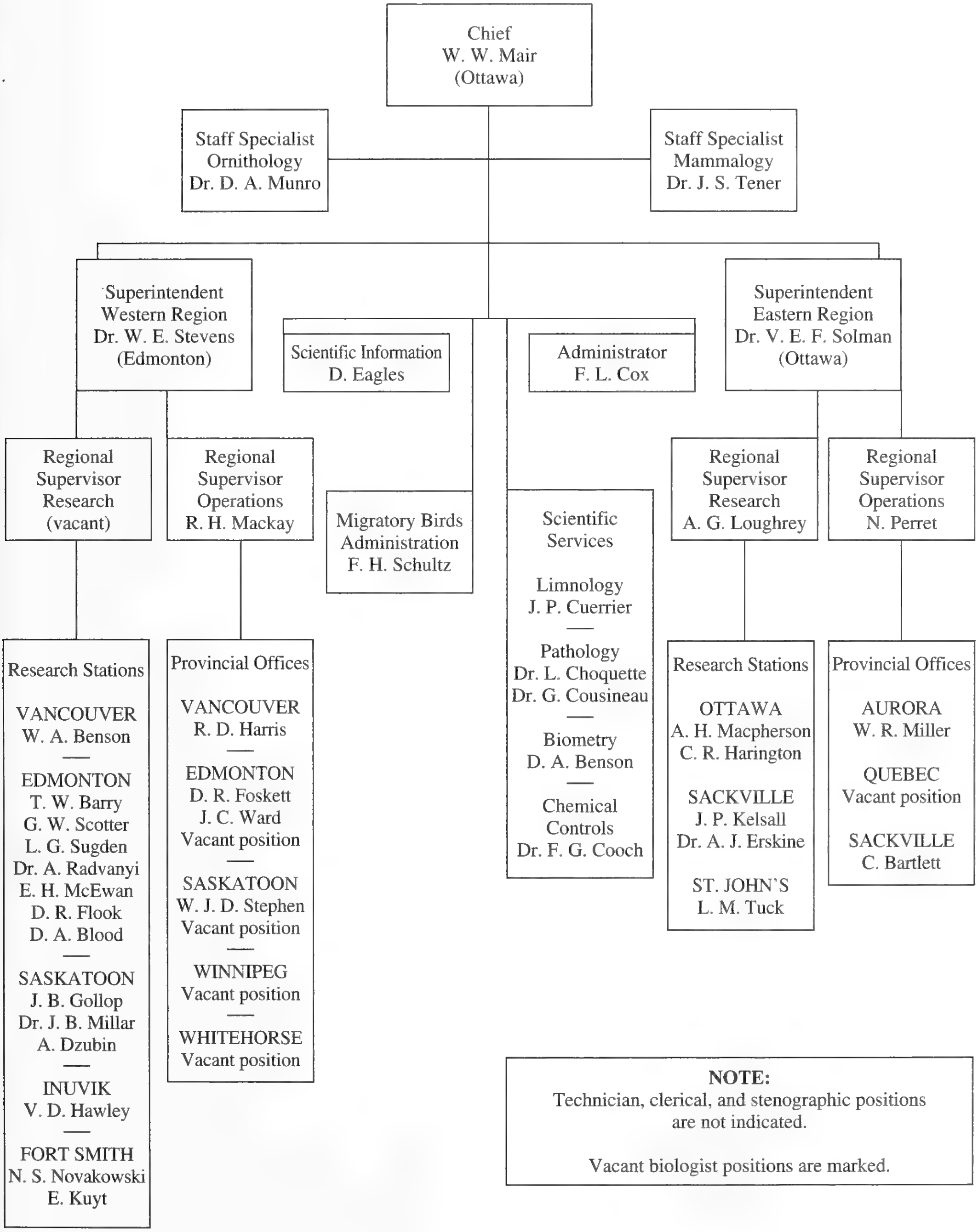
> i) To provide information for the proper administration and management of migratory birds throughout Canada and to carry out regulatory and management functions as required by the Migratory Birds Convention Act.
>
> ii) To conduct research and experimental management in all fields of ornithology, including ecology, as required to maintain optimum populations of birds for management, recreation, and other purposes....
>
> iii) To conduct research and experimental management in all fields of mammalogy including ecology as required to maintain optimum populations for management, recreation and other purposes....
>
> iv) To conduct research and experimental management in limnology and fish culture in the National Parks....
>
> v) To cooperate with other organizations directly and indirectly interested in wildlife research and experimental management at federal, provincial, and private levels, to ensure the best economy of funds and manpower, both in the Service and Canada-wide.
>
> vi) To keep under review the total wildlife research and management effort in Canada so as to advise the Department...and, on request, to assist other wildlife agencies in providing data for wildlife conservation.
>
> vii) To carry out or sponsor research...where such data are required for the maintenance of species and where such researches are not clearly within the purview of other existing wildlife research agencies.
>
> viii) To increase the proportion of its effort devoted to long-term fundamental and applied researches in the national interest as other research organizations develop sufficiently to undertake necessary ad hoc research.
>
> ix) To make the results of its work available to all wildlife agencies and to the public, through its own publications and through reports in scientific, professional, and other journals.
>
> x) To act as the coordinating centre for the dissemination of all wildlife research and management information throughout Canada.[6]

By 1960, the full-time staff that CWS could draw on to perform these tasks, as well as its regulatory, enforcement, and administrative duties, consisted of 40 full-time biologists and 53 technicians and administrative personnel. Apart from a small group of staff specialists attached to the head office in Ottawa, they were deployed widely across the country. CWS maintained offices in Vancouver (British Columbia), Edmonton (Alberta), Saskatoon (Saskatchewan), Winnipeg (Manitoba), Aurora and Ottawa (Ontario), Quebec City (Quebec), Sackville (New Brunswick), St. John's (Newfoundland), Whitehorse (Yukon), and Fort Smith and Inuvik (Northwest Territories).

That the role and reputation of the organization were gaining in stature can be inferred from the annual report of the Department of Northern Affairs and National Resources for that year. It was the custom, during the late 1950s and early 1960s, for each year's report to lead off with a thematic essay on one of the main areas of departmental responsibility. In 1959–1960, the chosen theme was "Wildlife in Man's World," and it reviewed both the history of wildlife exploitation and management and the role and responsibilities of CWS with greater clarity than in any previously published public document.

A similar theme was struck by Deputy Minister R. Gordon Robertson in his official welcoming remarks to the 25th Federal–Provincial Wildlife Conference, held in Ottawa in 1961. He stressed the important position of wildlife in the economy of Canada, especially in the north, where he referred to it as "a staple of life and the very basis of human existence."[7] His chosen topic was a reflection of the government's concentration on the "Resources for Tomorrow" Conference, which took place in August of that year. Close to 1000 participants gathered in Montreal to address the future of Canada's renewable resources. Of 80 background papers prepared for the conference, 11 dealt with wildlife. They included key papers on policy by Bill Mair and David Munro, a discussion of the recreational value of wildlife by Harrison Lewis, a comprehensive summary of the state of the fur industry by Alan Loughrey, and a discussion of emerging wildlife management problems by Bill Fuller, who had recently left CWS to take a position with the University of Alberta.[8] One wildlife-related initiative that emerged from that conference was the creation of the Canadian Wildlife Federation, a citizens' coalition of some

CANADIAN WILDLIFE SERVICE — 1961



Source: Adapted from Canadian Wildlife Service, *Canadian Wildlife Service Research Progress Report — 1961* (Ottawa: Queen's Printer, 1963)

750 anglers' and hunters' groups representing about 150 000 members nationwide.[9]

Early in the following year, CWS underwent its first major reorganization since 1953. The national organization, directed from a single centre in Ottawa, was decentralized into two divisions, west and east. Policy decisions would continue to be made at headquarters by the Chief and a cadre of senior staff specialists. Fieldwork, including not only research and wildlife management operations but administration, public relations, and interagency contacts, would be coordinated within the regions (as shown on page 57).

Although office locations, and, in many instances, the individuals occupying them, remained unchanged, the restructuring did introduce a new layer of administration between the formulation and the implementation of policies and programs. To that extent, at least, many of those who experienced it remember the event as marking a significant change in the culture of the organization.

In fact, it was a time of many changes. The 26th Federal–Provincial Wildlife Conference, chaired by David Munro as Acting Chief of CWS, took place in Fredericton on 5–6 April 1962. On that occasion, several important administrative and legislative developments were announced. Inspector A. M. Cart of the RCMP reported on the formation of a special squad of five full-time officers who would be assigned specifically to enforce regulations under the Migratory Birds Convention Act. In preparation for their new duties, they would follow a special training program in ornithology, law, and habitat familiarization under the guidance of David Munro and Hugh Schultz of CWS (see Chapter 2).

A second important notice came from A. T. Davidson, Director of the Agricultural Rehabilitation and Development Branch of the federal Department of Agriculture. He advised the delegates that the passage of the Agricultural Rehabilitation and Development Act the previous year was intended to facilitate multiuse planning for rural lands and natural resources. He invited wildlife managers and agencies to participate in exploring the possibilities of using marginal lands for wildlife production, conservation, and outdoor recreation (see Chapter 6).[10]

Third, David Munro observed that one of the topics addressed at the "Resources for Tomorrow" Conference had been the question of a national wildlife act aimed, in part, at promoting research that would be supportive of provincial wildlife programs. In response to this interest, and to a related proposal by the Honourable Mr. Westewood, Minister of Conservation and Recreation for British Columbia, CWS had been directed to draft a statement outlining the type of cooperative action that could be taken in the area of joint research. Quoting from the statement, Munro noted:

> There is a need for an increase in fundamental research...[including] such problems as the self-regulation of animal numbers; the determination of the effects of pesticides on populations; the effects of animal parasitism and disease; and the achievement of a better understanding of the physiological and behavioural processes of these birds and mammals....
>
> The Federal Government proposes to examine, by pilot projects on the prairies (the continental "duck factory") what are the best means of maintaining breeding habitat....Similarly, it will examine the problems affecting other migratory birds in other areas....
>
> The Federal Government would be prepared to provide all its research findings to the provinces. It would also be prepared to consider the establishment, on a cooperative basis with the provinces, of a reference and information centre on wildlife matters which could be used as a clearing house for the exchange of information among all wildlife agencies in Canada. This centre could be used as a source of material for public information bulletins and leaflets for the media of mass communications.[11]

Whether it was evident at the time or not, the discussions of law enforcement, land use, research, and public information at the 1962 conference in Fredericton would set the agenda for the activities of Canadian wildlife agencies in general, and of CWS in particular, for the next 10 years and more.

Notes

1. Graham Cooch, personal communication. Much of this increase reflected the network of Arctic sanctuaries established at Bylot Island, Cape Dorset, East Bay, West Hudson Bay, Queen Maud Island, Cape Parry, Banks Island, Kendall Island, and other sites, by Tom Barry and Graham Cooch. These sites afforded protection to all the Snow Goose nesting colonies then known to exist in northern Canada.
2. "Resolutions of the 1957 Conference," in *Minutes of the 22nd Federal–Provincial Wildlife Conference*, 17–18 June 1958, St. John's, Newfoundland (Ottawa: Canadian Wildlife Service, 1958), page 3.
3. *Minutes of the 22nd Federal–Provincial Wildlife Conference*, 17–18 June 1958, St. John's, Newfoundland (Ottawa: Canadian Wildlife Service, 1958), pages 14–15.
4. *Minutes of the 23rd Federal–Provincial Wildlife Conference*, 18–19 June 1959, Ottawa (Ottawa: Canadian Wildlife Service, 1959), page 37.
5. V. E. F. Solman, "Wildlife research and the role of the Canadian Wildlife Service" in *Wildlife Management Papers Delivered at the 21st to 24th Federal–Provincial Wildlife Conferences* (Ottawa: National Parks Branch, 1959).
6. Solman, "Wildlife research," pages 80–81. (See note 5)
7. *Minutes of the 25th Federal–Provincial Wildlife Conference*, 15–16 June 1961, Ottawa (Ottawa: National Parks Branch, 1961), page 1.
8. Canada, Department of Northern Affairs and National Resources, *Resources for Tomorrow: Conference Background Papers, Volume 2* (Ottawa: Queen's Printer, 1961).

9. *Minutes of the 26th Federal–Provincial Wildlife Conference*, 5–6 April 1962, Fredericton (Ottawa: Canadian Wildlife Service, 1962), page 47.
10. A. T. Davidson, "Agricultural Rehabilitation and Development Program" in *Minutes of the 26th Federal–Provincial Wildlife Conference*, 5–6 April 1962, Fredericton (Ottawa: National Parks Branch, 1962), pages 54–65.
11. D. A. Munro, "On federal–provincial cooperation in wildlife research and management" in *Minutes of the 26th Federal–Provincial Wildlife Conference*, 5–6 April 1962, Fredericton (Ottawa: National Parks Branch, 1962), pages 72–77.

CHAPTER 4. Working with Mammals

Although the Migratory Birds Convention Act ensured a certain priority for ornithological studies, the long, close relationship of CWS with the National Parks Branch and the mandate to advise the territorial governments about wildlife demanded a broader approach to biological studies. The specialties of limnologists, parasitologists, botanists, and habitat ecologists were all in demand. Mammalogy, however, was the one discipline that could fairly be said to have rivalled the study of birds as a preoccupation of CWS.

The National Parks

Much of the work was routine. Canada's national parks protect large areas of natural habitat, but their horizons are by no means limitless. Prospering populations of Elk, Moose, or Bison can literally eat themselves into a crisis if their numbers grow, unchecked, beyond the carrying capacity of the available range. It is the natural way of curbing overpopulation. However, the spectacle of starving animals, emaciated and plagued by parasites and disease, had no place in the tableau of unspoiled nature sought by the ecotourist. National Parks authorities had long recognized that healthy populations of wildlife, and especially of large mammals, were among their greatest assets in the campaign to attract vacationing visitors.[1] In some parks, prime specimens were even confined in enclosures close to the tourist accommodations to ensure that the public would experience a satisfying encounter with the native fauna.

The presence of tuberculosis and brucellosis among Bison has been a matter of concern to CWS throughout its history. In the summer of 1951, biologist Bill Fuller conducted a study to determine the incidence of both diseases in the Bison population of Wood Buffalo National Park (Photo credit: E. McEwan).

Furthermore, a policy of leaving population management entirely at the mercy of natural forces could put at risk the very ecosystems that the parks were created to preserve. One of the early assignments of the newly formed Wildlife Service, therefore, was to maintain systematic monitoring of mammal health and habitat in national parks and to recommend management intervention as appropriate, including the culling of herds and the live capture of animals for reintroduction to other locations.

Many CWS mammalogists participated in this work over the years, but a few dominated the field at the outset. The name of Frank Banfield turns up repeatedly in summary activity reports concerning the mountain parks, although his professional reputation owed even more to his pioneering work on Barren-ground Caribou. Bill Fuller, one of the earliest appointees to CWS (in 1947), blazed a trail in Bison studies at Wood Buffalo National Park that led ultimately to his earning a Ph.D.

Some parks projects involved general wildlife and habitat surveys. Others, involving the capture and relocation of given numbers of Beaver, Elk, Caribou, or Moose from parks where they were plentiful to parks where they were rare or nonexistent, were very specific. Especially in the case of large mammals, successive annual reports illustrate strong parallels between wildlife management and the handling and disposition of agricultural livestock. Thus, in 1948, 503 Bison, 250 Elk, and 100 Moose were culled in Elk Island National Park in order to protect the range. A further 33 Elk were removed from the Waterton Lakes National Park herd, as well as 55 Elk and six Bison at Banff.[2] Relocations of various species of mammals (Bison, Caribou, Muskox) continue from time to time up to the present day.

In 1949, steps were taken to establish an ongoing framework for an ecological survey of the National Parks of Canada. On 14 July, Hugh Keenleyside, Deputy Minister of Resources and Development, established a coordinating committee for this purpose with Vic Solman as secretary and Harrison Lewis as chairman. The committee held its first annual meeting on 4 February 1950.[3]

Wildlife studies were carried out under the guidance of this committee in Prince Albert, Elk Island, Jasper, Waterton Lakes, Yoho, Kootenay, Riding Mountain, Wood Buffalo, and Point Pelee national parks. Researchers investigated the biology of a variety of big game species. Donald A. Blood examined interactions between cattle and Elk in and around Riding Mountain National Park[4] and undertook a long-term study of mountain sheep in Jasper National Park.[5] Donald R. Flook devoted 10 years (1957–1967) to intensive research of Elk populations in the western mountain parks.[6] John S. Stelfox explored the ecology of Bighorn Sheep in Jasper, Banff, Waterton Lakes, and Kootenay national parks.[7] L. N. (Lu) Carbyn looked into the abundance of Wolves in the parks and evaluated their role as predators on large prey species.[8]

During the 1960s and 1970s, a growing level of environmental sophistication began to manifest itself in the public perception of national parks. Gradually, the preservation of representative ecosystems emerged as an important raison d'être for the establishment and management of protected areas. In addition to conducting field studies and providing management advice, CWS mammalogists now contributed to the long-range ecological planning process of the Parks Branch. Thus, in 1967–1968, for example, Lu Carbyn found himself engaged in describing the nature and extent of rough fescue prairie in Prince Albert National Park. The analysis included examinations of the influence of Elk, Moose, deer, and small mammals and the encroachment of Aspen Poplar on this native grassland type.[9] Ungulates were a particular focus of ecological studies in the Atlantic region parks as well, where John Kelsall investigated Moose in Fundy National Park and Ed Telfer, and subsequently Charles Drolet, studied forage production, ungulate feeding habits, and the impact of forest cutting practices on wildlife in Maritime forests.[10]

Studies like this were widespread. Andrew Radvanyi probed the influence of small mammals on forest regeneration in western Alberta. George Scotter proposed that alpine ecosystems in parks be subjected to an extensive evaluation of their structure and composition, before being made accessible to visitation by the public.[11] He was also a pioneer in researching the value of controlled burning in grassland habitats in Prince Albert and Waterton Lakes national parks as a means of eliminating detritus, promoting the regeneration of native flora, and improving range for wildlife.

A careful analysis of habitat usage by wildlife can be of critical importance in the selection of sites for visitor facilities. Where single species had been the focus of most earlier investigations in the mountain national parks, the emphasis now shifted increasingly to an assessment of integrated biotic communities. In 1971, for example, Laszlo Retfalvi reported on ecological inventories conducted by CWS in Jasper, Yoho, and Glacier national parks in order to ensure that construction of roads and buildings would not encroach excessively on critical wilderness areas. "Humans can so overrun the wilderness," he wrote, "that it can become incapable of functioning as an ecological entity. We must therefore define the point at which this can occur and ensure that our activities do not destroy our wilderness."[12]

As long as CWS remained a division of the National Parks Branch, involvement in large mammal management and ecological research within the parks was an unquestioned part of the agency's man-

The close association of CWS with the National Parks Branch often worked to the benefit of both agencies. Here, in the summer of 1961, biologist Don Flook scans the Red Deer River Valley, Banff National Park, for signs of Elk and other large mammals (Photo credit: D. Thomas).

date. Even in 1965, when the Wildlife Service was promoted to full branch status within the Department of Indian Affairs and Northern Development, the fact that it remained a sister agency in the same department encouraged close cooperation with Parks.

In 1971, however, the federal Department of the Environment was created, and CWS was assigned to the new department while the Parks Branch was not. In an effort to bridge the interdepartmental gap, an agreement was drawn up between Parks Canada and the Environmental Management Service, under which CWS had been subsumed. The terms of this protocol committed Parks to supply 16 person-years to sustain CWS positions for parks-related work and to contribute to operating budgets for initiatives in which the branch had an interest, such as wildlife inventories and large mammal management. In addition, major studies were conducted at many key sites within the national parks, on the environmental impact of visitors on soils, vegetation, and wildlife. Although subsequent realignments of departmental affiliation and responsibility tended to underline the arm's-length relationship between the two organizations, CWS and Parks continued to sustain a variety of joint projects, some collaborative and some contractual, until 1984, when the imposition of budget cutbacks effectively ended their historic partnership in wildlife management.

Several CWS staff participated in planning for potential national park sites in Canada's far north. The list included Axel Heiberg Island, Bathurst Inlet, Bylot and northern Baffin islands, Cape Parry, the Melville Hills, Nahanni, Thomsen River, and Wager Bay. Several have since been designated as parks, preserving large areas of significant Arctic wildlife habitat.[13]

Pathology

CWS assessments of large mammal range and population conditions inevitably led to consideration of a wide range of animal health issues. The annual culling of large mammals in the parks afforded an ideal opportunity to check for indications of diseases and parasites, and during its first decade of operations, CWS addressed a variety of problems. Two examples among many pathology studies that were undertaken in the early years dealt with tularemia in Beaver and Muskrats[14] and the distribution of disease-carrying ticks in Banff National Park.[15]

There were also occasions when direct intervention, rather than research, was required. In 1952, Nicholas S. (Nick) Novakowski, then working as assistant to Bill Fuller, identified an outbreak of rabies at Fort Fitzgerald, Alberta.[16] Over the next year, the epidemic spread widely across the north, and CWS biologists were called upon to bring it under control, collecting specimens for diagnosis of suspect animals and assisting the RCMP in a campaign to vaccinate every domestic dog and cat in the Northwest Territories. John Kelsall had vivid memories of the experience:

> In Yellowknife we set up our clinic in the fire hall and, day after day, people brought sled dogs, pet dogs, all sorts of dogs....
>
> One day when the temperature stood at -48°F., we had been vaccinating a series of dog teams. Two small girls, perhaps 7 or 8 years old, were standing quietly in a corner, watching the proceedings. Eventually my police companions went home for lunch, but still the two little girls lingered on. Finally I asked them if there was something they wanted and they replied that they would like to have their dog vaccinated. I said, "Fine. Bring him in." They answered, "We have him right here," and one of the girls opened up her parka hood and out stuck the tiny, hairless face of a Mexican chihuahua! I had had no idea that there was such an animal in the whole of the Northwest Territories and it surely looked curious to see one out on a day when it was 48 degrees below zero.[17]

In 1957, the Wildlife Service engaged its first veterinary pathologist, Harold C. Gibbs, to join a 14-member field research team investigating the condition of the Barren-ground Caribou.[18] Gibbs resigned in 1958, and Laurent P. E. Choquette, formerly of the Institute of Parasitology at Macdonald College of McGill University, was appointed in August 1959 to head up a Pathology Section. In 1961, a second pathologist, J. Guy Cousineau, and a technician, J. P. Couillard, joined the unit. Over the next five years, the Pathology Section undertook studies of diseases and parasites in Arctic Fox, Muskrat, Bison, and Caribou. Their interests extended even to the diseases of fish at the hatchery in Jasper National Park.[19]

In the early 1960s, dogs still played a critically important role in Arctic transportation. When studies indicated that not only rabies, but infectious hepatitis and distemper as well, threatened the health of dogs and their owners, CWS, in collaboration with the Health of Animals Branch of the Department of Agriculture, launched a counteroffensive. Under Choquette's direction, more than 14 000 doses of vaccine were distributed to communities in Arctic Quebec and Baffin Island.[20]

Domestic animals were not the only ones to suffer from epidemics, however. The annual culling of Bison in Wood Buffalo National Park provided an ideal opportunity to monitor the population for diseases such as tuberculosis and brucellosis. Year after year, the results of the tests confirmed that the transfer of Plains Bison to the northern park had introduced these diseases to the habitat of the Wood Bison (see Chapter 1). Then, in 1962, 281 mature Bison were found dead in the Hook Lake area just east of the park. The cause of death was diagnosed as anthrax, a bacterial infection. The carcasses were burned and buried, but the following summer another 12 animals died of anthrax around Hook Lake, and 270 more were found dead in the Grand Detour area just outside the park boundary. In 1964, 300 died.[21]

Because the anthrax organism remains viable for a long time in the environment, efforts were begun in 1963 to divert the herds away from infected areas by building fences across northward migration routes. In 1964, efforts were made to herd the Bison into safe areas. It was not until 1965 that a concerted attempt was made to capture and vaccinate the animals. Between March and October of that year, 4291 Bison from Wood Buffalo National Park and the Hook Lake area were vaccinated. Another 4161 doses were administered in 1966, the year in which Guy Cousineau left CWS and Eric Broughton and George Gibson joined the Pathology Section.[22]

No cases of anthrax were reported in either 1965 or 1966, and the vaccination program was suspended in 1967. That year, 120 Bison died of the disease. When vaccine was administered again in 1968, 1969, and 1970, a single death was recorded in the first year and none in the next two.

The vaccination program was the first attempt ever to control an anthrax epidemic in a wild population. Although it did not eliminate the risk of the disease, it demonstrated the possibility of preventing sudden, large-scale outbreaks.[23]

Although the work of the CWS veterinary pathologists is treated here in the context of disease epidemics among large mammals, this was only one part of their work. Choquette, Broughton, Gibson, and their colleagues were invaluable advisors on a wide range of issues relating to the health and well-being of wildlife. They participated in developing methods for tranquillizing, immobilizing, and handling animals for testing and for shipment. They became experts in the identification of avian and mammalian parasites. They provided advice on the identification and management of outbreaks of disease in waterfowl and on the management of birds kept by aviculturists under permit from CWS. When Broughton's position was declared "surplus to departmental requirements" in the budgetary cutbacks imposed on Environment Canada in the fall of 1984, J. Anthony (Tony) Keith lamented:

> I honestly don't know how we are going to replace his skill....There isn't another wildlife veterinarian on staff anywhere in Canada. Eric...specializes in wildlife and makes house calls all the way from the gull colonies on Toronto's Leslie Street Spit to the caribou herds near Tuktoyaktuk.[24]

Fortunately, Broughton's expertise was not wholly lost to Canada's wildlife. Following the Environment Canada layoffs, he transferred to a position with Agriculture Canada in which he was available to consult from time to time with his former colleagues in CWS.

Bison

Nowhere in Canada's national parks was herd management a more complex challenge than in Wood Buffalo National Park. Concern about the survival of the Wood Bison, the northern subspecies of the North American Bison, had been expressed as early as the 1890s, when it was suspected that the remnant population in the area south of Great Slave Lake and west of the Slave River might well be no more than 250.[25] Here, by the 1920s, thanks to protective game regulations and enforcement, the free-ranging Wood Bison herd had grown to an estimated population of 1500 head.[26] In 1922, a federal Order-in-Council declared a large part of this area to be a national park. In 1926, the Peace–Athabasca Delta area was added to it, so that the new preserve straddling the Alberta–Northwest Territories border encompassed nearly 45 000 square kilometres of sub-Arctic plain.

Ironically, within three years of the creation of the park, the Wood Bison population was subjected to a greater risk than ever by the decision to move animals from the overcrowded national herd of Plains Bison from Buffalo Park near Wainwright, Alberta, to the new location. Between 1925 and 1928, a total of 6673 animals were shipped northward by rail and barge.[27] Although the Plains Bison prospered, the move could hardly be hailed as a success. The two populations interbred freely, and by 1940 it was widely believed that the "pure" Wood Bison genetic strain had been lost through hybridization of the two subspecies.[28] Worse still, as early as 1947 it was evident that the animals from the tuberculosis-infected Wainwright herd had introduced the disease to the hitherto uninfected range of Wood Buffalo National Park.

There was a lot of excitement, therefore, in 1957, when a small herd of Bison was sighted from the air in a remote area of the park near the Nyarling River. The location, the appearance, and the isolation of this group from the large herds of plains hybrids all argued in favour of the possibility that this might be a remnant population of Wood Bison. CWS biologist Nick Novakowski travelled to the area by snowmobile to investigate. He remembers:

> I could tell they were different as soon as I saw them. Ten or a dozen distinctive features were visible right away. They were taller, for one thing, less round in the barrel and with a higher, sharper hump. They didn't have as large a cape, or thick, hairy chaps extending down the front legs. Also the wood bison has a smaller beard and a darker coat. We knew what they were, all right.
>
> On top of that, we knew that the plains bison migrated a considerable distance from summer to winter range. These animals were only travelling about 10 miles from season to season. Their movements were very restricted, and they occupied an area that was nowhere near any of the other herds.[29]

Novakowski collected five specimens to be sent to the National Museum. His expectations were confirmed when word came back from Ottawa that these animals were probably the closest thing to the pure Wood Bison subspecies still in existence.[30]

The existence of an isolated population with a noticeably high proportion of Wood Bison characteristics triggered an immediate call for protective measures. In 1963, a decision was made to build up the population by establishing a captive breeding herd. To begin with, 77 animals were captured from the Nyarling River herd in February 1963. Since it was important that the breeding herd be disease free, they were tested for tuberculosis and brucellosis on the spot. More than half were rejected. Nineteen animals, presumed to be free of disease, were transported by truck to a holding facility near Fort Smith, where they were tested a second time, five months later.

By this time, anthrax outbreaks at other locations in the park had put the long-term prospects for a successful captive population in jeopardy. In order to minimize the risk that the selected group of healthy Wood Bison might become infected, Ward Stevens, then Superintendent of the CWS Western Region in Edmonton, decided they should be removed from the area without delay.[31] Accordingly, 18 of the animals were transplanted to a newly created Mackenzie Bison Sanctuary located 300 kilometres to the northwest, on the north side of the Mackenzie River.[32] The bison were carried by barge from Fort Smith to Fort Providence and then, by truck, to a release site some 25 kilometres from the town.

Novakowski was confident that they would adapt readily to the site. It had been selected after a thorough evaluation of range potential, in consultation with mammalogist Ward Stevens and Walt Jeffrey, a forest hydrologist with expertise in vegetation types. When the animals were turned loose, however, he was dismayed to see that they appeared to have no intention of staying in the chosen location.

> As soon as we let them go, they just took off like quail. We weren't that far off in our evaluation, though. They found a place that was more to their liking about 15 miles away, and there they settled down to stay.[33]

The transplant to the Fort Providence area was highly successful and a tribute to the sound science and careful handling methods of Novakowski and the CWS Pathology Section. The herd increased rapidly, doubling in size approximately every three years.[34] By the mid-1990s, an estimated 2690 Wood Bison were roaming the Mackenzie Bison Sanctuary. Meanwhile, in 1965, another 21 disease-free Bison from the Nyarling River area were moved to Elk Island National Park. There they formed the basis of a breeding Wood Bison herd that subsequently provided foundation stock for transplants to a variety of additional sites in Alberta, Manitoba, Yukon, and the

Northwest Territories. By the mid-1980s, several small but viable herds of Wood Bison, descended from the Nyarling River/Needle Lake stock, were widely dispersed across the northern prairies. This fact undoubtedly influenced the recommendation of the Bison Recovery Team, in 1987, that the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) should downgrade the status of the Wood Bison from Endangered to Threatened.[35]

Wood Bison have continued to provide CWS biologists in the Prairie and Northern Region with rich opportunities for research up to the present time. The work of Lu Carbyn, for example, has greatly extended knowledge of predator–prey relationships between Bison and Wolves.[36] Since 1973, CWS biologist Hal Reynolds has been deeply engrossed in studies of both Wood Bison[37] and Plains Bison, including range and food habits studies, recovery efforts, and the thorny question of what to do about the Plains/Wood Bison hybrid population.[38]

The successful transfer of Wood Bison to other locations stimulated interest in adopting a rigorous Bison management plan with the ultimate goal of replacing the hybrid herd with a large, disease-free population of "pure" Wood Bison inside Wood Buffalo National Park itself. As outlined in 1968, this 20-year initiative would have called for the enclosure of all major groups of Bison within fenced reserves where they could be tested for disease and culled. Healthy Wood Bison would then be reintroduced into areas of the park from which the prior stock had been removed. As the Wood Bison herd increased, the remaining hybrid and Plains Bison stock in the park would be systematically eliminated.[39]

Several negative factors — cost, scale, and the likelihood of public resistance to massive culling — doomed this plan. By the late 1960s, however, natural influences were beginning to intervene. From a level of about 11 000 in 1969, the Wood Buffalo National Park Bison population dropped sharply to slightly over 5000 in 1977 and has continued to decline more gradually since that time. The largest single factor in this decline was the loss by drowning of some 3000 animals in 1974, but climatic and range conditions, predation, and disease have all taken a toll.[40]

Although it had been known since the mid-1940s that tuberculosis was present in the park Bison, it was not until 1988 that a Bison Disease Task Force identified tuberculosis and brucellosis as posing serious challenges to the health of the herd.[41] Again, a proposal was put forward to apply drastic measures. It entailed rounding up Bison, testing them for disease, establishing disease-free breeding herds representing the various genetic groups within the park, and eliminating the diseased and surplus animals. Eventually, it culminated in a project to repopulate the park with healthy stock that were more representative of the Wood Bison type.

CWS favoured this approach as being the best way to correct the errors committed in the 1920s, when the diseased Plains Bison had been transferred from Wainwright. Ranchers with cattle grazing on summer range in the vicinity of the park also supported this point of view. A Federal Environmental Impact Assessment and Review Panel, one member of which was the same Bill Fuller who had pioneered Bison studies in the park in the late 1940s, held hearings on the subject in 1990. Their report stated unequivocally that:

> Eradication of the existing bison population is the only method of eliminating the risk of transmission of bovine brucellosis and tuberculosis from bison in and around Wood Buffalo National Park to domestic cattle, wood bison, and humans.[42]

However, there were other interests involved. Parks Canada was reluctant to support a strategy that ran counter to the perception of parks as areas where wildlife should be immune from killing. Native people in northern Alberta and the Northwest Territories felt they should have a voice in management decisions concerning a species that was such a powerful icon of their ancient hunting traditions. The outcome, for the time being, was a decision to defer action until further studies could be completed. In April 1995, the Government of Canada announced that it would fund additional research on Bison ecology. Thirty years after his first involvement with diseased Bison in Wood Buffalo National Park, Eric Broughton was named a consulting pathologist to the study. And there the matter rested at the time of writing.

Furbearers

Outside the national parks, a large proportion of CWS work with mammals occurred in Canada's northern territories. Although wildlife management was a territorial responsibility, the Wildlife Service provided extensive scientific advice on the topic to the governments of the territories in the years before those governments established their own expertise. In addition, the interests of the federal agency specifically included migratory birds and other species that regularly crossed provincial, territorial, or international boundaries (e.g., Caribou) or were subject to international conventions (e.g., Polar Bear and certain Caribou populations).

A matter of particular concern, especially in the early years of the Wildlife Service when trapping and the fur trade constituted an important part of the northern economy, was the ecology of fur-bearing mammals. Studies of marten, Fisher, and Beaver took place in the District of Mackenzie from 1947 to the 1970s.

Farther east, during the 1950s and 1960s, Andrew H. Macpherson researched population fluctuations among Arctic Fox populations in the Keewatin and Franklin districts.[43] Although most of this study, which eventually formed the foundation of Macpherson's doctoral thesis, took place in the Arctic, where he located and examined more than 200 dens, he did transport a pair of foxes south one year, from the Thelon Sanctuary to Ottawa, in order to pursue his investigations over the winter using captive animals. The experiment was not wholly successful, but it revealed at least one remarkable characteristic of the species — an unexpectedly strong homing instinct. Some time after their arrival in the city, the foxes escaped. Both had been tagged, so it was not entirely surprising when Macpherson received word that one of the pair had been trapped. What surprised him was the location where the little fugitive was taken. The trapper who returned the tag worked a trapline near James Bay, 750 kilometres or more to the north of the nation's capital.[44]

Some of the most extensive research into the biology and ecology of a commercially valuable fur-bearing mammal, however, was focused on the Muskrat, a species that for many years has accounted for approximately 50% of the total number of pelts taken by trappers in Canada.[45] In the south, Muskrat studies were often a corollary to projects involving waterfowl habitat and wetland conservation. In the north, Ward Stevens had begun doing Muskrat research in the Mackenzie Delta in 1947[46] and earned a Ph.D. on the strength of it. Stevens' initial demonstration of the importance of fur trapping to the northern economy led to extensive additional studies. He was followed at the CWS outpost in Aklavik by Eoin H. McEwan, who in turn was succeeded by Joe Bryant in 1955.

Bryant's task combined ecological and population research with a somewhat broader mandate to advise local trappers and the territorial government on how to manage the animals with a view to improving the long-term quality and productivity of the fur harvest. It was a period of profound change in northern Canada. The introduction of the family allowance and the expansion of many community services such as education and health care had created strong social and economic incentives for seminomadic trapping families to take up more or less permanent residence in the settlements where schools and clinics were established. As a result, Muskrat and other wildlife populations close to the principal centres of human settlement were absorbing the brunt of the trapping effort, while farther afield the animals were virtually untouched.

Working on the premise that successful resource management should result in both a sustainable yield of pelts and a better income for the trappers, Bryant undertook a survey of furbearers along the Arctic Red River. He demonstrated that wildlife population densities increased with distance from the settlement. However, the logic of his research findings was insufficient to alter the choice of most of the people in the area to relinquish life on the trapline in favour of modern conveniences.

Pathologist Eric Broughton (*rear*) and technician Pete Cuillard begin the autopsy of a Canada Goose to determine the cause of death (Photo credit: J. Foley).

It would have been a serious mistake to presume that the native people of the Arctic were insensitive to the changes in their world. This point was brought home to Bryant in the course of an encounter with trappers of the Old Crow band in the northern Yukon. These people still lived off the land in the late 1950s and were heavily dependent on Muskrats for a large part of their income. When they noticed white spots in the livers of many of the rats that they trapped, they feared that an epidemic of some sort might wipe out their fur supply. A message was relayed via the RCMP requesting that the young CWS biologist fly over from Aklavik to assess the situation. In his own words:

> The RCMP at Old Crow made arrangements for a local trapper to act as my guide and marked an "X" on the map, identifying one of the myriad lakes in the Old Crow Flats for our rendezvous. In late March I flew over from Aklavik with two weeks' supplies and landed at what the pilot and I hoped was the right lake. I unloaded

my stuff and the plane took off while I sat there, hoping that this really was point "X."

Not long after, I heard a dog team coming. It was my guide, Charlie Peter Charlie, chief of the Old Crow band, who incidentally received the Order of Canada a few years ago. We were pretty close in age — probably both still in our 20s — and we hit it off right away. I spent two weeks there, going each day to a different trapper's camp. In the evening as they skinned their rats, I examined the carcasses. It turned out to be a relatively benign parasitic infestation.

Something happened on my first night there, though, that was critical to the success of the whole trip. Charlie and I had eaten supper and were just settled back, talking, when he asked if I knew anything about hydatid disease. Now, hydatid disease is a parasitic infection that generally cycles through dogs or wolves and caribou. Humans can take the place of the caribou in the cycle and the cysts can form in many parts of the body — the liver, the lungs, the meninges of the brain. It can get quite nasty.

Frankly, I was surprised Charlie even knew the word but since I had been giving a series of public talks on the topic over on the Mackenzie side I gave him the whole spiel. He sat and nodded and when I was done, he reached into his pack and pulled out a three page typed manuscript on hydatid disease that Ian McTaggart-Cowan had prepared for the warden service in northern British Columbia. Now, this man had never been to school a day in his life. He had taught himself to read and write. But when he got that paper, he saw its significance and sat down and typed out a copy for every head of family in Old Crow. He knew it as well as I did. I'm certain that if I had tried to snow him I would never have seen the document and would have had less cooperation for the rest of the trip. I was lucky to know the topic he chose to test me on.

There's a post script to the story. The incidence of hydatid disease was probably lower in Old Crow than in any of the communities on the Mackenzie side, largely because when Charlie received the information he immediately insisted that all sled dogs coming into the community be kept penned or tied, and that people be careful in washing their hands after working with dogs. It was a matter of sanitation and it worked.[47]

Eventually, CWS obtained its own registered trapping area in the Mackenzie Delta, in order to study major fur-bearing species without interfering with the activities of working trappers. During the 1960s, Vernon D. Hawley conducted extensive population research on Muskrat, Beaver, mink and marten in this area.[48]

Muskoxen

In 1951, about four years before Joe Bryant was posted to Aklavik, a young biologist named John Tener received a summons to the office of Harrison Lewis. Tener, a former Royal Canadian Air Force pilot, had completed a degree in wildlife biology and, on the recommendation of Ian McTaggart-Cowan, one of his professors at the University of British Columbia, had obtained a job with the Wildlife Service as a Dominion Wildlife Management Officer for Ontario and Quebec. In this capacity, he had made an ecological survey of Point Pelee National Park, conducted the 1951 census of the Quebec North Shore seabird colonies, and worked on problems of crop damage by birds at the federal Experimental Farm in Ottawa.

Despite the concentration on ornithological work, Tener's real interest was in mammals, and Harrison Lewis was well aware of it. As Tener remembered it in later years, the interview that would shape his life for the next decade went like this:

Lewis could be quite an abrupt man. When I entered his office, he turned to me and said "What do you know about muskoxen?"

And I said, "Nothing, sir."

And he said, "Neither does anyone else, so you're going to go and find out."

And that's how I became the government mammalogist for the districts of Franklin and Keewatin, which basically meant the whole of the eastern Arctic mainland and the Arctic Archipelago.[49]

Tener was not the only CWS biologist to devote time to the study of Muskoxen. John Kelsall, whose principal research was focused on Caribou, filed a report on *The Muskoxen of the Thelon*.[50] Kelsall's comments in that document revealed something of the spirit of discovery that animated his research, especially when he referred to his satisfaction at being able to observe, at close range, animals about which the literature of the day contained little information "other than scattered, fragmentary bits in the writings of [earlier] explorers."[50]

John Tener felt a similar sense of wonder from the moment he began his first summer among the Muskoxen on the Fosheim Peninsula on the west side of Ellesmere Island. A year later, he did aerial surveys of summer and winter ranges of the Thelon Game Sanctuary, northeast of Great Slave Lake.[51]

When I started studying Muskoxen, I was the only person doing it. Various explorers had written about the animals, but I was interested in doing a complete study — life history, ecology, and so forth. Eventually I broadened it to include the taxonomy of the species as well. In 1952 I started working on the barren grounds. Made a canoe trip down the Thelon River for a couple of months, studying Muskox populations.[52]

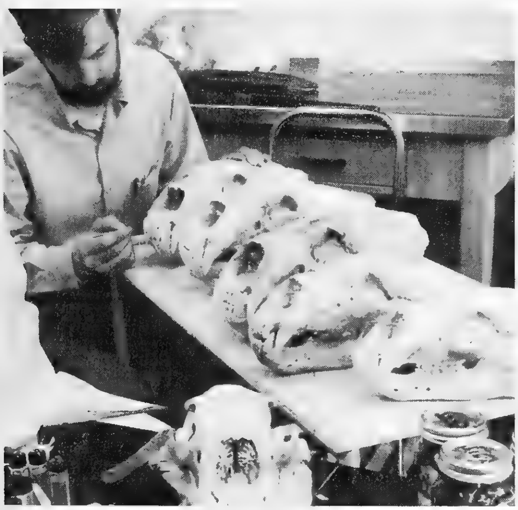
In the fall of 1952, Tener was accepted at Oxford to pursue doctoral studies for a year. When he came back, he was assigned to projects in the western parks for a year before returning to Ottawa in 1954 to resume his Arctic work. In 1955 and 1956, he travelled the Back River, a century after Chief Factor James Anderson of the Hudson's Bay Company had traversed the same route.

It was quite interesting to get hold of [Anderson's] journals and compare what he had seen and what I observed. It was surprisingly similar, although I saw fewer Caribou and Muskoxen. After his time, the buffalo robe industry had been wiped out on the plains and for a time interest turned north where thousands of Muskoxen were slaughtered.[53]

The Back River trip in 1956 took Tener and Dean Fisher of the Fisheries Research Board about six weeks by canoe. It was the kind of experience that etched scenes into memory:

> One evening, we had portaged around a set of rapids and were ready to load up again. It had been an overcast day, but at sunset there was a break in the clouds and the whole scene was bathed in a golden light. Suddenly the hair on the back of my neck rose — something I'd never experienced before — and I turned around to see two people appearing against the black sky over the top of a little hill. Two people in caribou skin clothing. One was a man carrying a rifle. The other, his wife, carried a quarter of a caribou. We sat and visited for a while, though they spoke no English and I no Inuktitut. Then they helped us reload the canoe, and in appreciation I gave him a tin of tobacco and her a pound of tea and they were very pleased with that. Anyway, we said goodbye and went on till we found a campsite. We could see down the shore of Pelly Lake the white tent of this Eskimo couple. Next morning, we heard a little twittering sound outside the tent. That's how Inuit would announce their presence. We invited them in. We didn't have much food left, but we had some tea and biscuits and Dean had set out nets to catch fish. They must have seen that because about noon they came back and gave us some smoked caribou tongue — just lovely stuff.[54]

In 1959, CWS Chief Bill Mair decided Tener should write up his muskox work. He did so and submitted the resulting thesis to qualify for his doctorate in 1960. The work was published in 1965 as an illustrated monograph that is still a key contribution to the literature on one of the most intriguing of Arctic mammals.[55]



Biologist Dick Russell examines the skulls of Polar Bears during the 1960s. Comparison of details enables the researcher to determine differences in age and in the characteristics of different populations of bears (Photo credit: G. Ben).

Polar Bears

Rare indeed is the CWS biologist who has returned from field studies in the Arctic without at least one Polar Bear tale to tell. For many Arctic hands, the giant white bears embody both the romance and the danger of the north more effectively than any other species. Self-assured in their role as top predators of the Arctic ecozones, they seem compelled by an inherent curiosity to investigate the activities of interloping scientists, most of whose studies are not aimed at the bears at all. Thus, seabird researchers, such as Les Tuck in the 1950s, David Nettleship in the 1970s, and Tony Gaston, Gilles Chapdelaine, and others in the 1980s and 1990s, all encountered Polar Bears in the course of their studies of Thick-billed Murre colonies on Arctic islands as widely spaced as Digges, Akpatok, Bylot, and Prince Leopold.

The study of the Polar Bear as a species in Canada became the special interest of a smaller group of biologists, starting with C. Richard (Dick) Harington in 1961. It was at that time that concern began to be expressed that a fashionable demand for Polar Bear pelts might place undue pressure on the population. Harington was to study the life history, ecology, and biology of the Polar Bear, with a view to making recommendations for its conservation. The initial fieldwork took place on Southampton and Banks islands, concentrating on life history, annual patterns of activity, hunting methods, food habits, and denning behaviour.[56]

Interest in and support for this work increased following a conference of circumpolar nations, held in Alaska in September 1965 to discuss the status of the Polar Bear throughout its range. Canada's representatives at that meeting were John Tener and Dick Harington. One outcome of the conference was an invitation by the International Union for the Conservation of Nature and Natural Resources (IUCN) to take on the role of collating research and sharing the findings among researchers of Canada, the United States, the Soviet Union, Denmark, and Norway, the five nations in whose territory the Polar Bear occurs.[57]

As part of Canada's contribution to this effort, the CWS Polar Bear program was expanded by Charles J. (Chuck) Jonkel and R. H. (Dick) Russell with studies to collect data on migration, growth rates, mortality, and productivity. This work, begun at Cape Churchill in the fall of 1966, involved trapping, marking, and recapture of a large number of bears. During the first three years of the project, from October 1966 to the end of 1969, about 150 bears were captured in the southern Hudson Bay area. In addition to being marked with lip tattoos and ear tags, some of the bears were fitted with collars to which radio transmitters were attached to enable them to be tracked in their wanderings. Although some bears do travel long distances, it was found that many in the Hudson Bay study area remained within a few hundred kilometres of where they were tagged.[58] In a related research project, CWS contracted with Thomas H. (Tom) Manning to study the physical characteristics and measurements of Polar Bear specimens around the world. His report, *Geographical Variation in the Polar Bear*, indicated the existence of discrete populations, rather than one homogeneous circumpolar population.[59]

The international dimension of this work was extended in January 1968 with the formation of a permanent international committee of scientists, known as the Polar Bear Specialists Group, under the auspices of IUCN. Two representatives were nominated to this committee from each of the five Polar Bear countries. The group met again in 1970 and in 1972, and eventually their deliberations culminated, on 15 November 1973, in the signing of the International Agreement on the Conservation of Polar Bears (Polar Bear Convention) in Oslo, Norway. This document, giving formal recognition to the commitment of each of the signatories to long-term protection of the Polar Bear, came into effect with ratification by three of the nations in 1976. The remaining two adopted it in 1978.[60]

Meanwhile, Canada had brought forward its own domestic initiative with regard to Polar Bear conservation, establishing a Federal–Provincial Committee for Polar Bear Research and Management as early as 1969.[61] A year later, another mammalogist, Ian Stirling, joined the CWS Polar Bear team. Although he had previously been studying seals, it soon became clear that the white bears would be the chief passion of his professional life. Some of his earliest work entailed fitting bears with radio transmitters designed by CWS bioelectronics specialist Fred Anderka and tracking them to establish and map their territories, seasonal patterns of movement, and migration routes. Close to three decades of intensive work with the species stand behind Stirling's reputation as one of the world's foremost authorities on Polar Bears. Throughout his career, he promoted interest in the species in Canada and abroad and stressed the importance of Inuit participation in the development of a successful management program for Polar Bears in Canada.

The study of live Polar Bears can be a high-risk occupation, especially if the specimen of the day is not suitably contained or tranquillized. Probably no one engaged in Arctic research for the Wildlife Service ever had a more intimate opportunity to learn this lesson than Frank Brazeau. In the spring of 1972, Brazeau was working with Chuck Jonkel, flying by helicopter out of Resolute on Cornwallis Island, in search of female Polar Bears recently emerged from their winter dens. When they found one, they darted it with a tranquillizer from the air, then landed to mark the adult bear and any cubs she might have.

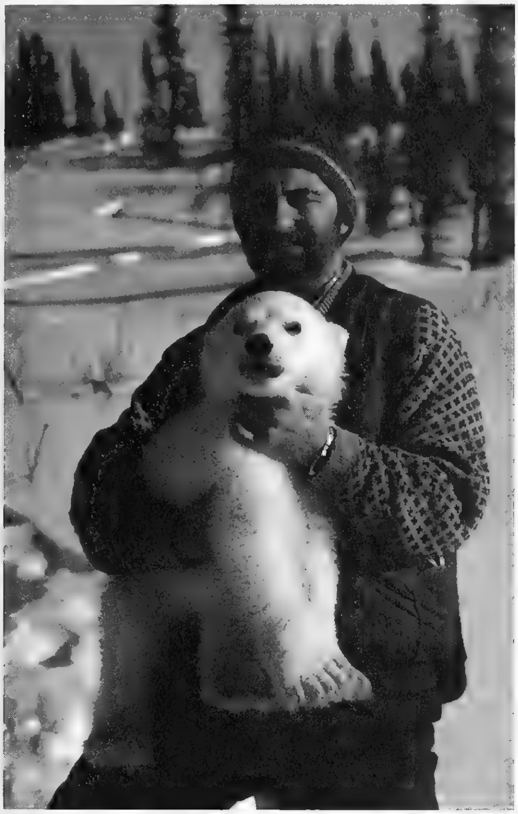
As part of the study, Jonkel wanted to examine vacated dens as well, and after marking a bear they would sometimes attempt to backtrack along its trail in the hope of finding the winter quarters, a cave hollowed out of the snow. On the day in question, they found one in a large snowbank that had accumulated in the lee of a slope. Unbeknownst to them, it was not the den from which their tranquillized bear had come.

While Jonkel went to the mouth of the den, Brazeau climbed the bank and began probing the snow with a stick to determine the location of the inner chamber. When Jonkel peered in, he was alarmed to discover that the snow cave was occupied. He turned to warn Brazeau, but at that moment the bear, perhaps alerted by the sound of footsteps overhead, exploded upwards through the snow, seized Brazeau, and pulled him downward into its lair. Thinking his last moment had come, Brazeau lashed out instinctively, kicking, flailing, and punching at his assailant. The bear struck back, batting upwards with a paw so powerful that it sent Brazeau through the roof of the den and sprawling out onto the snow. The bear emerged in hot pursuit but, confronted with frantic shouting and the din of the helicopter, it ran off, allowing time for Jonkel to drag Brazeau aboard the aircraft and take off for the return flight to Resolute before the bear could renew its attack.[62]

In fact, Polar Bears could sometimes be put at risk by their encounters with the researchers as well. Because the animals varied greatly in size, it was sometimes difficult to calculate the size of dose large enough to put a bear safely to sleep but small enough to ensure a rapid recovery from its effects. Occasionally, as Ian Stirling recalled in his book, *Polar Bears*, a mistake could happen. When it did, there was nothing for it but to apply artificial respiration, not mouth-to-mouth, but by rolling the animal on its side, gripping its fur, and lifting and lowering to expand and compress the rib cage to maintain a steady exchange of air. One such incident under the midnight sun stood out in his memory:

> Shortly before midnight, I spotted an adult female bear and darted her [from the helicopter]. She went down quickly. On the ground I discovered that she was much thinner than she had seemed from the air. The dosage was too strong and she stopped breathing fairly soon after we reached her so I started artificial respiration. It was cold, about -20°C....
>
> I kept pumping air into her until 2:00 a.m. I knew she would survive, but I was still awfully glad when the old girl started breathing on her own so we could go home, have a cup of tea, and go to bed.[63]

Never before had Stirling had to assist a bear's breathing for so long, and he worried about the possibility of long-term side effects. He was relieved,



Ian Stirling holds a Polar Bear cub prior to tagging and weighing it. The 1991 data are part of a long-term study in the James Bay/Hudson Bay area on the impacts of climatic change on the condition and reproductive success of Polar Bears (Photo credit: A. E. Derocher).

therefore, to capture the same bear the next spring and to find her in good health and caring for newborn cubs. As an epilogue to the tale, he was able to write: "It was clear she had not suffered unduly from her interlude with science."[64]

Some bears were not so lucky. During the late 1970s, as interest grew in the topic of mineral resource extraction in the Arctic, questions arose in the Polar Bear Specialists Group and at IUCN as to what might happen to a Polar Bear if its coat were contaminated by an oil spill. Four bears were captured, and three were exposed to small quantities of oil. The results were alarming. The bears attempted to clean the oil from their fur by licking and became ill. Two of the three died. The fourth bear was released, and the testing was halted at once.[65]

Because of Canada's international commitment under the Polar Bear Convention, study of this species was sustained even after 1984, when much CWS mammal work was curtailed as a result of budget cutbacks. Chemical contamination has been an ongoing topic of research. In the early 1970s, CWS toxicologist Gerald (Gerry) Bowes found high levels of polychlorinated biphenyls (PCBs) in Polar Bear tissue samples.[66] The discovery was one of several pieces of evidence that atmospheric and oceanic currents were transporting contaminants to the polar regions of the Earth. In recent years, the monitoring of contaminant levels in Polar Bears has been a major interest of Ross J. Norstrom of the CWS toxics section (see Chapter 8).[67] Other recent studies by CWS and other Canadian agencies and institutions have addressed a wide variety of subjects, from feeding, metabolism, and energetics to distribution and ecology.[68]

Ian Stirling has continued to play an important part in this trend to an increasingly inclusive approach to Polar Bear studies. In the early 1990s, for example, he was disturbed to note a decline in the survival of Polar Bear cubs in the James Bay/Hudson Bay area. The problem seemed to be correlated to a reduction in the amount of body fat on adult bears, leading him to suspect that the milder winters associated with global warming trends might be reducing the length of time during which the large predators could get out on the ice to catch and consume seals. With less time to accumulate fat reserves, female bears might be less than adequately equipped to produce and support strong, healthy young. A longer, colder winter in 1992 gave him and an associate, Andrew E. Derocher, the opportunity to test the hypothesis, and sure enough, bears that they tranquillized and measured the next fall were fatter and in better health than they had been in preceding years.[69]

Another of Stirling's long-standing interests is the ecological significance of polynyas, biologically productive areas of year-round open water in the Arctic ice pack. Huge concentrations of plankton, fish, seals, whales, and Polar Bears gather in these locations, especially during the winter months. Since the mid-1970s, Stirling has been exploring these complex webs of relationships,[70] and in the fall of 1997 he was laying plans for yet another expedition to the vast North Water polynya that lies between Ellesmere Island and northern Greenland.

Caribou

Long before the arrival of European settlers, the nomadic aboriginal people of western and northern Canada depended for their survival on an intimate relationship with migratory herds of large mammals. On the prairie grasslands, the Bison was the foundation of life, and when it was hunted to the verge of extinction, the Plains Indian culture nearly disappeared as well. Farther north, the Caribou played a similar role, especially for the people of the vast inland barrens. Caribou meat and fat were the foundation of their diet; Caribou hides could be made

Many CWS biologists survived aircraft mishaps over the years. This Cessna 180 flipped on landing at Pipestone River, Saskatchewan, on 29 November 1957. While the pilot signalled for help, Ernie Kuyt, who was engaged in the Cooperative Barren-ground Caribou Study, got on with the job of collecting and examining specimens (Photo credit: E. Kuyt).

into soft, fur-lined clothing, babiche for snowshoe webbing, durable leather tents, and kayak covers; Caribou sinews made tough thongs and fine thread, while Caribou bone slivers could be fashioned into awls and needles. Indeed, it would have been hard to imagine a viable tundra society without the Caribou.[71]

An estimated 2 to 3 million Caribou roamed the Arctic tundra and sub-Arctic taiga regions in the early 1900s. It was therefore a matter of serious concern when wildlife investigators of the 1920s and 1930s began to report that this population might be in decline. Between 1925 and 1927, W. H. B. Hoare investigated Caribou in the central Arctic and recommended that remedial conservation measures be implemented. Ten years later, in 1936–1937, C. H. D. Clarke reiterated a similar concern following an extended study in the Thelon Game Sanctuary.[72]

No further action was taken during the war years, but in 1948, Frank Banfield began an extensive study of Barren-ground Caribou on behalf of CWS.[73] John Kelsall continued this work through 1950–1951, Alan Loughrey took it on for 1951–1952,[74] and Kelsall resumed it in 1952–1953 after returning from educational leave.[75]

By 1950, the estimated population of Barren-ground Caribou had fallen from 2 million or more to about 670 000 animals.[76] Northern administrators, well aware that starvation could strike the Inuit camps of the barrens with disastrous results if the trend continued, accelerated the level of investigation. Discussions of Caribou management questions at the Federal–Provincial Wildlife Conference led, in 1953, to the creation of two committees.[77] One, the Technical Committee for Caribou Preservation, initiated and conducted field activities. The other was an Administrative Committee to coordinate policy between the federal, provincial, and territorial jurisdictions whose boundaries the Caribou crossed in the course of their seasonal migrations.

Much of the emphasis in Caribou research at this time was on aerial surveys to locate and count the principal herds. Some work, however, such as calving studies and summer range assessments, required biologists to get down on the ground. It was on such an expedition that David Munro and Eoin McEwan found themselves in the spring of 1953, encamped on the Firth River in the northwest corner of the

You can't keep a CWS biologist down for long, but with his leg in a cast, Caribou specialist John Kelsall was willing to put his feet up for a few minutes on a sunny morning at his camp on Artillery Lake, NWT, and enjoy a second cup of coffee (Photo credit: R. Fyfe).

The Kaminuriak Study (1966–1968) was a comprehensive field examination of the biology and ecology of one of the major Barren-ground Caribou populations of the Northwest Territories. Here, Gerry Parker (*centre*), assisted by two Inuit, checks the identification collar on a swimming Caribou (Photo credit: CWS).

Yukon. They had travelled inland by dog team, over the sea ice from the RCMP post at Herschel, to observe the westward movement of Caribou along the foothills of the British Mountains. Once the ice was out, they expected to be picked up by Mike Zubko, a pilot from Aklavik, who would be able to land on the river with his pontoon-equipped Cessna 170. In retrospect, Munro remembered the expedition quite positively:

> Our time in camp was useful and personally rewarding. The caribou eventually came through our area. We observed the behaviour of cows and calves at the time of calving and we got the sex and age counts we wanted. We lived surrounded by Rock and Willow Ptarmigan and saw all aspects of the onset of their breeding season.

Because of the critical importance of country food to the well-being of many residents of the north, reproductive success was of particular interest in many Caribou studies. Here, at Beverly Lake on 16 June 1960, Ernie Kuyt (*l.*) and Don Thomas (*r.*) examine two young calves, one albino and one with "normal" coloration (Photo credit: E. Kuyt).

> The day we were to be picked up passed, and we had no idea why; our radio had never worked from the time of our arrival. By a week after the rendezvous date we had eaten most of the food that we had brought with us. As I recall we still had some powdered milk, tea, hardtack, and a can of bacon, but nothing else to speak of. We had also run out of tobacco and had been experimenting, without satisfaction, with dried cranberry leaves.
>
> On the tenth day of our wait, I shot a caribou, since it seemed certain that we would need it. Just as I began to skin and gut and butcher it, I heard the sound of an approaching aircraft. Sure enough, it was Mike. He had been held up because he had needed new floats and these had been delayed beyond the expected date in their passage down the Mackenzie by barge from the south.
>
> None of this was particularly exceptional, and it seemed of little consequence at the time.[78]

This sort of nonchalant, "all in a day's work" attitude was something of a trademark among CWS Arctic hands. In a 1996 interview, Alan Loughrey reminisced, tongue in cheek:

> I used to amuse my children with stories of my harrowing heroics. I'd say, "What do you want to hear tonight? Lost in the barrens winter, spring, or summer?" They were a captive audience with no choice but to listen.[79]

The Caribou surveys were extended eastward in 1954–1955, to investigate the status of Woodland Caribou in northern Quebec, in cooperation with the provincial Department of Game and Fish. In 1956, a similar cooperative study was launched in Newfoundland and Labrador.

Meanwhile, the summer of 1955 saw John Kelsall and Alan Loughrey conducting a resurvey of the continental range of the Barren-ground Caribou in response to concerns of the Territorial Council. Each spent about six weeks on aerial reconnaissance that year, Kelsall in the Yukon and western Northwest Territories out of Yellowknife, Loughrey to the east in Keewatin, on the Melville Peninsula, and along the Arctic coast to the mouth of the Back River.

As a result of that summer's investigation, the estimated population of Barren-ground Caribou was again adjusted sharply downward, to 278 000.[80] Anticipating the possibility of a serious crisis, game and conservation officials of the governments of Canada, the Northwest Territories, and the provinces of Manitoba, Saskatchewan, and Alberta all agreed to collaborate in financing and organizing a field research venture of unprecedented proportions in the annals of Canadian wildlife management. The Beverly herd was chosen as the target population for this study. It was a large population of Barren-ground Caribou that wintered in northern Saskatchewan and took its name from its calving area in the vicinity of Beverly Lake in the Northwest Territories.

Under the leadership of John Kelsall of CWS, the 14-member team assembled for the project was a virtual who's who of northern biologists.[81] The task force was to examine the status and behaviour of the herd under eight headings: movement of the herd; predation; population; human use; calving; range studies; effect of windchill on calf survival; and accidents, parasites, and diseases.[82]

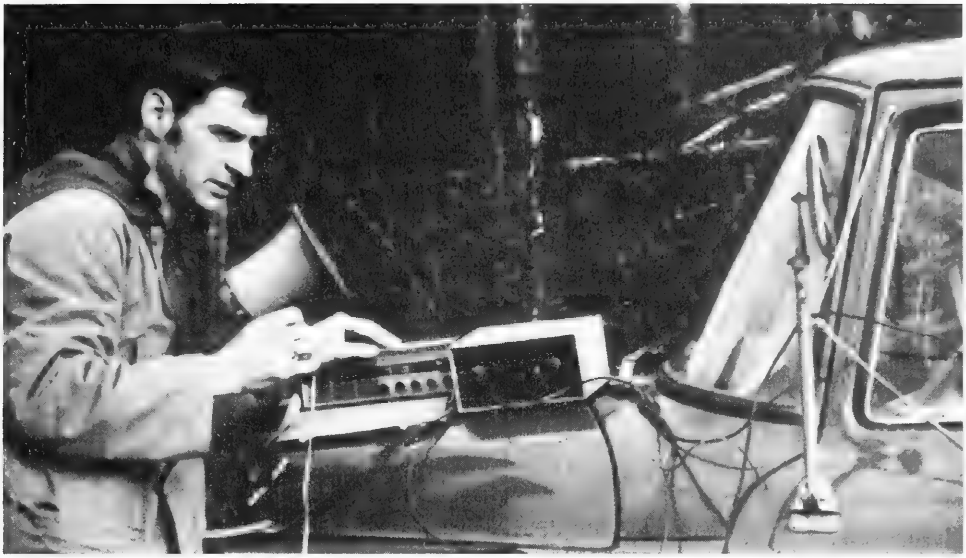
Fieldwork began in April 1957, when the herd was fully launched on its northward migration along a front about 240 kilometres wide. Most of the team members lived in tents on the tundra and taiga of Canada's central Arctic for a large part of the next 18 months. They covered more than 250 000 kilometres by aircraft and over 2400 by dog-team. And even the most seasoned field researchers sometimes encountered moments that could not be expressed adequately by statistics. One member of the team wrote:

> [The caribou] poured over the hills, flowed up the valleys, running to a new patch of green vegetation, then stopping to feed while those behind ran to fresher vegetation ahead....
>
> The clacking of their hoofs, the constant blatting of the fawns, the grunting of the females, the constant coughing and wheezing, all made a roar that was deafening. Then some bolted from my scent; the movement spread to about 1,000 and the ground fairly shook with the pounding hoofs, the roar increased. Each stampede only affected a thousand or so, then sort of petered out....[83]

The study gathered a wealth of data, from which reports were generated on predation by Wolves, the impact of harsh weather conditions at calving time, accidental drownings, and poor range quality, especially in burned-over areas. In terms of a broad, general conclusion, however, it appeared that the largest single cause of Caribou mortality was harvesting by humans armed with high-powered rifles. In 1956–1957, for example, human utilization consumed 9.4% of the herd, while net recruitment of young amounted to only 8.1%. Between 1956 and 1958, the estimated strength of the Beverly herd, believed to represent nearly half the Barren-ground Caribou on the Canadian mainland, fell from about 100 000 animals to 85 500.[84]

The Wolf issue was a recurring one. Bill Mair had prior experience with predator control in British Columbia and was well aware of the pros and cons of the practice. He assigned the task of Predator Control Officer to Alan Loughrey, who held strongly to the view that "control" was the operative word, not eradication. To carry out the program, Loughrey engaged six barren-ground trappers and hunters to cover the central barrens.[85] The wooded winter Caribou range between Great Slave Lake and Great Bear Lake was covered by Rae Stewart of CWS, while Loughrey and his crew chief, Wilf McNeil, took care of the area south of Great Slave Lake to the Alberta and Saskatchewan borders. Over two successive winters (1957–1959), more than 2200 Wolves were killed. The result of this program, in combination with milder weather during several succeeding calving seasons in the early 1960s, was a gradual increase in herd numbers.

Several members of the task force suggested that fire on the winter range of Barren-ground Caribou



Predator–prey relationships have long been a subject of study for CWS mammalogists. Here, research biologist Lu Carbyn plays back the sound of howling, using an amplifier and speaker, to help locate Wolf rendezvous points in Jasper National Park (Photo credit: CWS).

could also be a major factor in the population decline. Bill Mair recruited George Scotter from the Range Science Department at Utah State University to study this possibility. Scotter examined winter ranges in northwestern Manitoba, northern Saskatchewan, and the Northwest Territories,[86] initiating research that was continued in later years by Donald (Don) Miller and Donald C. (Don) Thomas.

Further Caribou work included a detailed analysis of nutritional requirements, carried out by Eoin McEwan under the joint sponsorship of CWS and the University of British Columbia. It was not until 1966, however, that another extended field study of Barren-ground Caribou got under way. This time, the target was the Kaminuriak herd, a large group that wintered in northern Manitoba. Like the Beverly herd to the west, this group had also declined in size, dropping from about 125 000 in the late 1940s to between 30 000 and 70 000 a decade later.[87] Now, however, current information from provincial and territorial game officers as well as annual kill estimates from the RCMP were raising hopes that the population trend might have halted or even turned around.

Andrew Macpherson was named to head the study. The researchers included T. Charles (Chuck) Dauphiné, who was to assess the condition and reproductive success of the animals; Don Miller, who would conduct winter range studies; Frank L. Miller, whose study focused on the age structure of the herd; and Gerry Parker, who would track seasonal distribution and migration. Gaston Tessier, senior technician and laboratory manager for the Eastern Region, was also attached to the team.

The collection of specimens was an inevitable part of such a large-scale field study. In a little over two years, close to 1000 Caribou of all ages were shot. Understandably, there were times when such bloody and serious science had to be countered with a bit of irreverence and levity. One such occasion remained vividly in Gerry Parker's memory 30 years after the event:

> One day in 1966, we had shot quite a number of Caribou and were just settling down to skin them out. As we worked, the talk turned to what you could eat on the land. Andrew Macpherson sliced off a piece of meat from the animal he was cleaning, and turning to one of our Inuit helpers said, "Would you eat this?" and without a moment's hesitation swallowed the still-warm, raw meat. The guide, not to be outdone, did the same thing. Andrew continued the challenge with a bit of kidney, some liver, and so on, and the Inuit matched him bite for bite.
>
> Finally, Andrew peeled back a flap of skin from the back of the animal and picked up a fat warble fly larva on the tip of his knife. "How about this?" he crowed, and popped it into his mouth. At that, the native man doubled over laughing. "You white men may be crazy enough to eat that," he said, "but not me!"
>
> At that, Andrew started to laugh as well, and I will never forget the image of him, sitting there grinning and chuckling, with caribou blood dripping down his red goatee.[88]

Needless to say, Macpherson and his team did not personally consume all the Caribou specimens that were collected. Rather, after the necessary measurements and samples had been taken, the meat was transported by plane to the aboriginal communities nearest to the field party's current location, to be distributed among the residents.

The Kaminuriak study provided answers to a wide variety of questions on the ecology of Barren-ground Caribou living in a particularly harsh environment. It also suggested that herd numbers had stabilized and perhaps begun to recover following the precipitous decline in population that had marked the 1950s. Parker estimated that the Kaminuriak herd, prior to calving in 1968, stood at over 63 000 animals.[89]

CWS biologists found themselves working with Caribou in a wide variety of circumstances in the late 1960s and early 1970s. Two attempts at transplanting populations to areas where the species had been extirpated are worth mentioning. One of the locations was Southampton Island, where the local Caribou population had been hunted out of existence in the early 1950s. In June 1967, a crew under the direction of Tom Manning ferried 51 animals to Southampton Island from nearby Coats Island. In the summers of 1970 and 1971, Gerry Parker conducted a range evaluation of the island and projected Caribou population growth.[90] The transplanted herd adapted well to the new surroundings and has prospered since.

Less successful was an attempt to reestablish Woodland Caribou in Cape Breton Highlands National Park. An initial transfer of 18 animals from Laurentides Provincial Park was made in 1968 with the cooperation of the Quebec Department of Tourism, Fish, and Game. Forty more were brought in from an area north of Sept-Îles, Quebec, the following year. Despite early optimism, however, the project failed. Subsequent research suggested that the Cape Breton Highlands habitat had become contaminated by a parasitic nematode, *Parelaphostrongylus tenuis*, that is carried with impunity by White-tailed Deer but is deadly to Caribou.[91] Parasitic "brain worms" may not have been the sole cause of the failure, however. Nick Novakowski recounts a tale of poachers who were apprehended, were charged with killing Caribou, and had their guns confiscated. The event took on a comic twist when it transpired not only that one of the offenders was the cousin of the judge presiding over the trial in Cheticamp, Nova Scotia, but that the gun he had been using belonged to the jurist as well.[92]

Yet another transplant venture involved the attempt to introduce Reindeer, the domesticated Eurasian race of the Caribou, to the Mackenzie River Delta. With the objective of supplementing dwindling wildlife resources and laying the foundation for an industry that might improve the economic conditions of the region, the Government of Canada purchased 3000 animals from Carl Lomen, the so-called "Reindeer king of Alaska." The 2600-kilometre trek from western Alaska to the Mackenzie Delta took more than five years to complete.[93] After passing through a series of owners and managers, responsibility for the herd was assigned to the Wildlife Service in 1968 so that scientific studies of the animals and their range might be undertaken by biologist George Scotter, with a view to ensuring a high yield of meat at reasonable cost.[94]

Also in northwestern Canada, attention was shifting to the Porcupine Caribou herd, a native, transboundary population of about 110 000 animals that pass the summer grazing on the Alaskan and Yukon coastal plains, but migrate inland to winter in forested valleys. Initially, the focus of the investigators' interest was the degree to which human interventions in the environment, such as construction of the Dempster Highway linking Dawson to Inuvik, might influence the movements of the herd.[95] As knowledge of this migratory population grew, CWS and the Yukon Department of Renewable Resources undertook a broader, long-term study of range ecology from 1979 to 1987.[96]

By the early 1980s, the role of CWS vis-à-vis other participants in northern wildlife management was changing profoundly.[97] Increasingly, territorial governments were setting up regional resource managers to conduct their own surveys, and native groups were asserting their claims to a voice in the management of traditional rights and resources. In 1983, federal, territorial, and aboriginal signatories established the Beverly-Kaminuriak Caribou Management Board to oversee the well-being of the principal Caribou herds in the Northwest Territories. George Scotter served as the CWS representative to this group for its first five years, followed by Don Thomas. Over the years, the board has emerged as a ground-breaking model of cooperation and an unparalleled venue for successful amalgamation of scientific and traditional knowledge of game management.[98]

The success of the comanagement model in the Northwest Territories encouraged the creation of a similar body to deal with the Porcupine herd. An agreement to create the Porcupine Caribou Management Board was signed in October 1985, and its first meeting took place in June 1986. Membership, as befits a comanagement board, has consisted from the start of four aboriginal representatives and four from the federal and territorial governments. From the outset, CWS Caribou specialist D. E. (Don) Russell has been the federal presence on the Board.

Because the Porcupine Caribou population ranges on both sides of the Yukon–Alaska border, some form of international understanding also had to be worked out if a sound conservation strategy was to be put in place. On 6 July 1978, CWS launched an initiative to negotiate an agreement with the United

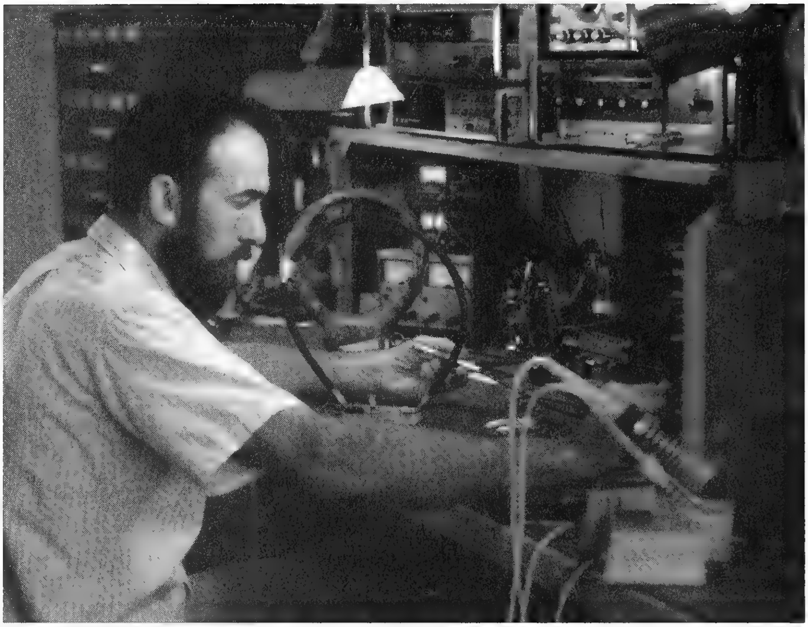
Undeterred by his close encounter with a Polar Bear in 1972, wildlife research technician Frank Brazeau returned to the high Arctic in succeeding years. This 1975 photograph caught him on the trail at Mokka Fjord on the east coast of Axel Heiberg Island (Photo credit: G. Parker).

States, coupled with a withdrawal of the northern portion of the Yukon from new development. Nine years later, on 17 July 1987, an International Agreement on the Conservation of the Porcupine Caribou Herd was signed on behalf of the Governments of Canada and the United States. Under this agreement, an International Porcupine Caribou Board was created to advise the Canadian, American Yukon, and Alaskan governments on relevant research and management issues. Again, government and native interests have equal representation. Art Martell of CWS was the founding CWS representative and cochairperson of this body. He was succeeded in this role by Don Russell.

While these developments were taking place on the Arctic mainland of North America, the attention of other CWS Caribou specialists turned to the status of the Peary Caribou, a diminutive subspecies found primarily on the northern islands of the Arctic Archipelago. Gerry Parker, Don Thomas, Eric Broughton, Dick Russell, and Frank Miller were among those who participated in these investigations, and what they found was disturbing.[99] The number of Peary Caribou had declined significantly since John Tener had conducted population surveys in the area some 15 years earlier.[100] Severe winters were resulting in low birth rates and high calf mortality. From an estimated population of 24 320 in the western Queen Elizabeth Islands in 1961, the population in that area had fallen, by the early 1970s, to fewer than 3000.[101] Based on the evidence of these studies, COSEWIC designated the Peary Caribou as a threatened population in 1979. Frank Miller continued to monitor the condition of the subspecies, finding evidence of further declines that convinced COSEWIC to upgrade the designation of the Peary Caribou from Threatened to Endangered in 1991.

In contrast to the declining Peary Caribou population, the George River herd of Woodland Caribou of northern Labrador and Quebec was growing rapidly during much of the same period. This population had first been surveyed in the mid-1950s, and interest in its status was revived in the late 1970s. Chuck Dauphiné and representatives of the provincial governments of Newfoundland and Labrador and Quebec began a study of the herd's distribution and migration. A key resource in this undertaking was Fred Anderka, whose expertise in designing and building radio tracking devices to fit a variety of species, including rattlesnakes, made CWS a world leader in this method of monitoring wildlife over vast and remote areas.

For a time, Charles Drolet continued the telemetry studies on the George River herd, as well as monitoring the physical and reproductive condition of the animals, in collaboration with the Naskapi people of Schefferville, Quebec. In the spring of 1980, Gerry Parker, who was now assigned to the Atlantic regional office of CWS, became involved in an extension of this work in Labrador under the Federal–Provincial Co-operative Wildlife Program. The study was requested because of concern over the future of the herd, which had grown to an estimated



Radiotelemetry has aided CWS field researchers enormously in tracing the movements of wildlife from afar. Much of their success in this work they owe to the particular talents of Fred Anderka (*shown here*), who designed and built radio transmitter collars for subjects ranging in size from ducklings to Polar Bears (Photo credit: CWS).

600 000 animals, the largest concentration of Caribou in the world. Accompanied by Newfoundland and Labrador biologist Stu Luttich, CWS technician John Maxwell, pathologist Eric Broughton, and health inspector Dale Duplessis of Agriculture Canada, Parker travelled to Nain, Labrador. There the team participated in a community Caribou hunt and examined Caribou shot by local hunters.

The information they gathered proved to be of particular interest to the Caribou management biologists of Quebec and Newfoundland and Labrador. It was also relevant to the mandate of a scientific review committee struck to assess the impact of low-level military flight training over an area of Labrador that had hitherto been widely assumed to have little significance for wildlife.

For a time following 1980, the George River herd continued to grow. It was this population that lost 10 000 of its members by drowning while crossing the flooded Caniapiscau River in northern Quebec in October 1984, an incident had appeared to have little impact on the size of the herd, which some estimated to be as large as 800 000. A herd of this size, it was generally agreed, was beyond the carrying capacity of the range.[102] Observations in the 1990s suggest that the size of the George River herd has diminished, perhaps below 500 000 animals, in recent years.[103]

Notes

1. Janet Foster, *Working for Wildlife: The Beginning of Preservation in Canada* (Toronto: University of Toronto Press, 1978), pages 55–56.
2. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), page 275.
3. Lewis, *Lively*, page 295. (See note 2)
4. D. A. Blood, *Range Relationships of Elk and Cattle in Riding Mountain National Park, Manitoba* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 1, Number 19, 1968).
5. Donald A. Blood, "Studies of Bighorn Sheep in the Mountain National Parks" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967).
6. D. R. Flook, *Causes and Implications of an Observed Sex Differential in the Survival of Wapiti* (Ottawa: Canadian Wildlife Service Report Series, Number 11, 1970).
7. J S. Stelfox, *Range Ecology of Rocky Mountain Bighorn Sheep in Canadian National Parks* (Ottawa: Canadian Wildlife Service Report Series, Number 39, 1977).
8. L. N. Carbyn, S. M. Oosenbrug, and D. W. Anions, *Wolves, Bison and the Dynamics Related to the Peace–Athabasca Delta in Canada's Wood Buffalo National Park* (Edmonton: University of Alberta,

Aircraft are not the only means by which CWS biologists have travelled in the Arctic. Here, Alan Loughrey and an Inuk guide take a rest before continuing a journey by komatik on Southampton Island during a study of the Atlantic Walrus in 1953 (Photo credit: CWS).

Canadian Circumpolar Institute, Circumpolar Research Series, Number 4, 1993).

9. L. Carbyn, "Description of the *Festuca scabrella* association in Prince Albert National Park, Saskatchewan," *The Canadian Field-Naturalist* 85: 25–30 (1971).
10. Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967), page 52.
11. More complete summaries of CWS field projects from the late 1950s to 1971 can be found in the following publications: Canadian Wildlife Service, *Canadian Wildlife Service Research Progress Report — 1961* (Ottawa: Queen's Printer, 1963); Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967); and Canada, Department of the Environment, *Canadian Wildlife Service '71* (Ottawa: Information Canada, 1971).
12. L. Retfalvi, "Biotic communities in the western parks" in Canada, Department of the Environment, *Canadian Wildlife Service '71* (Ottawa: Information Canada, 1971), page 55.
13. cf. G. W. Scotter, "Priority areas chosen for preserving Arctic oases," *Canadian Geographic* 105(1): 64–69 (1985).
14. cf. A. W. F. Banfield, *Tularemia in Beaver and Muskrats, Waterton Lakes National Park, Alberta, 1952–53* (Canadian Wildlife Service Archive, File Number CWSC 186).
15. A. W. F. Banfield, *Rocky Mountain Spotted Fever Investigation in Banff National Park 1953* (Canadian Wildlife Service Archive, File Number CWSC 13).
16. N. Novakowski, personal communication, interviewed at Ottawa, 26 November 1996.
17. Anecdote quoted in Lewis, *Lively*, page 435. (See note 2)
18. Lewis, *Lively*, page 385. (See note 2)
19. L. P. E. Choquette, J. Guy Cousineau, and Eric Broughton, "Pathology" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967).
20. Choquette et al., "Pathology," page 75. (See note 19)
21. E. Broughton, "Diseases affecting bison" in H. W. Reynolds and A. W. L. Hawley (editors), *Bison Ecology in Relation to Agricultural Development in the Slave River Lowlands, NWT* (Ottawa: Canadian Wildlife Service Occasional Paper Number 63, 1987).
22. Choquette et al., "Pathology," page 77. (See note 19)
23. L. P. E. Choquette, "Pathology" in Canada, Department of the Environment, *Canadian Wildlife Service '71* (Ottawa: Information Canada, 1971), page 78.
24. Quoted in B. Estabrook, "What price wildlife?" *Equinox* 20 (March/April): 79–91 (1985).
25. C. Gates, T. Chowns, and H. Reynolds, "Wood buffalo at the crossroads" in John Foster and Dick Harrison (editors), *Buffalo*, published as *Alberta: Studies in the Arts and Sciences* 3(1) (Edmonton: University of Alberta Press, 1992), pages 139–165.
26. G. MacEwan, *Buffalo: Sacred and Sacrificed* (Edmonton: Alberta Sport, Recreation, Parks & Wildlife Foundation, 1995), page 123.

27. W. F. Lothian, *A History of Canada's National Parks, Volume IV* (Ottawa: Parks Canada, 1981), page 34.
28. N. S. Novakowski, *Wood Bison* (Ottawa: Committee on the Status of Endangered Wildlife in Canada, Status Report, 1978), page 4.
29. Novakowski, personal communication. (See note 16)
30. A. W. F. Banfield and N. S. Novakowski, *The Survival of the Wood Bison (* Bison bison athabascae *Rhoads) in the Northwest Territories* (National Museum of Canada Natural History Paper Number 8, 1960).
31. Donald R. Flook, personal communication in letter to P. Logan dated 5 September 1997.
32. The establishment of the Mackenzie Bison Sanctuary had been facilitated by Alan Loughrey, who, at the time, was Head of Northwest Territories Wildlife Management Service (Loughrey, personal communication in a letter to P. Logan dated 14 May 1998).
33. Novakowski, personal communication. (See note 16)
34. Carbyn et al., *Wolves, Bison*, page 41. (See note 8)
35. Wood Bison Recovery Team, *Status Report* (Ottawa: Committee on the Status of Endangered Wildlife in Canada, 1987), page 71.
36. Carbyn et al., *Wolves, Bison*. (See note 8)
37. H. W. Reynolds and A. W. L. Hawley (editors), *Bison Ecology in Relation to Agricultural Development in the Slave River Lowlands, NWT* (Ottawa: Canadian Wildlife Service Occasional Paper Number 63, 1987).
38. H. W. Reynolds, "Plains bison conservation in Canada" in G. W. Holroyd, G. Burns, and H. Smith (editors), *Proceedings of the Second Endangered Species and Prairie Conservation Workshop*, January 1989, Regina (Edmonton: Provincial Museum of Alberta, Natural History Occasional Paper Number 15, 1991), pages 256–266.
39. Carbyn et al., *Wolves, Bison*, page 45. (See note 8)
40. Carbyn et al., *Wolves, Bison*, page 48. (See note 8)
41. Bison Disease Task Force, *Evaluation of Brucellosis and Tuberculosis in Bison in Northern Canada* (Ottawa: Agriculture Canada, 1988).
42. Robert Connelly, William Fuller, Ben Hubert, Rene Mercredi, and Gary Wobeser, *Northern Diseased Bison: Report of the Environmental Assessment Committee* (Ottawa: Federal Environmental Assessment Review Office, 1990), page 40.
43. A. H. Macpherson, *The Dynamics of Canadian Arctic Fox Populations* (Ottawa: Canadian Wildlife Service Report Series, Number 8, 1969).
44. G. R. Parker, personal communication, interviewed at Sackville, New Brunswick, 14 June 1997.
45. Statistics Canada, *Canada Year Book, 1988* (Ottawa, 1987), Chapter 8, page 31.
46. cf. W. E. Stevens, *The Northwestern Muskrat of the Mackenzie Delta, Northwest Territories, 1947–48* (Canadian Wildlife Service Wildlife Management Bulletin Series 1, Number 8, 1953).
47. Joseph E. Bryant, personal communication, 26 November 1996.
48. Vernon D. Hawley, "Muskrat, Beaver, Mink and Marten population studies in the Mackenzie Delta, Northwest Territories" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967).
49. John S. Tener, personal communication, interviewed at National Wildlife Research Centre, Hull, Quebec, 27 November 1996.
50. J. P. Kelsall, *The Muskoxen of the Thelon* (Canadian Wildlife Service Archive, File Number CWSC 196, unpublished report, 1951).
51. cf. J. S. Tener, *Musk-oxen Winter Range Survey, Thelon Game Sanctuary, 1952* (Canadian Wildlife Service Archive, File Number CWSC 195, unpublished report).
52. John S. Tener, personal communication, interviewed at Ottawa, 5 December 1996.
53. Tener, personal communication. (See note 52)
54. Tener, personal communication. (See note 52)
55. J. S. Tener, *Muskoxen in Canada. A Biological and Taxonomic Review* (Ottawa: Canadian Wildlife Service Monograph Series, Number 2, 1965).
56. C. R. Harrington, *Denning Habits of the Polar Bear (*Ursus maritimus *Phipps)* (Ottawa: Canadian Wildlife Service Report Series, Number 5, 1968), 30 pages.
57. *Proceedings of the First International Scientific Meeting on the Polar Bear*, held at the University of Alaska, Fairbanks, Alaska, 6–10 September 1965 (Washington, D.C.: United States Department of the Interior, Bureau of Sport Fisheries and Wildlife, Resource Publication 16; and University of Alaska, International Conference Proceedings Series, Number 1).
58. Canada, Department of the Environment, *Canadian Wildlife Service '71* (Ottawa: Information Canada, 1971), page 45.
59. T. H. Manning, *Geographical Variation in the Polar Bear (*Ursus maritimus *Phipps)* (Ottawa: Canadian Wildlife Service Report Series, Number 13, 1971).
60. The full text of the Polar Bear Convention can be found in an appendix to Ian Stirling's *Polar Bears* (Ann Arbor, Michigan: University of Michigan Press, 1991).
61. N. S. Novakowski, " Inaugural meeting of the Administrative Committee for Polar Bear Research and Management in Canada, Edmonton, Alberta, July 1970," *Biological Conservation* 2(4) (1970).
62. The present account of this story is a composite version, reconstructed from tellings of the tale by Frank Miller, Guy Morrison, Gaston Tessier, and Gerry Parker. Parker, in the company of Frank Brazeau, experienced a number of close encounters with Polar Bears on Melville Island two years later, in the spring of 1974.
63. Ian Stirling, *Polar Bears* (Ann Arbor, Michigan: University of Michigan Press, 1991).
64. Stirling, *Polar Bears*. (See note 63)
65. Stirling, *Polar Bears*. (See note 63)
66. C. W. Bowes and C. J. Jonkel, "Presence and distribution of polychlorinated biphenyls (PCBs) in arctic and subarctic marine food chains," *Journal of the Fisheries Research Board of Canada* 32: 2111–2123 (1975).
67. R. J. Norstrom, M. Simon, and D. C. G. Muir, "Polychlorinated dibenzo-p-dioxins and dibenzofurans in marine mammals in the Canadian north," *Environmental Pollution* 66: 1–19 (1990).
68. W. Calvert, I. Stirling, M. Taylor, M. A. Ramsay, G. B. Kolenosky, M. Crête, S. Kearney, and S. Luttich, "Research on polar bears in Canada 1988–92" in O. Wiig, E. W. Born, and G. W. Garner, *Polar Bears: Proceedings of the Eleventh Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 25–27 Jan-*

uary 1993, Copenhagen, Denmark (Gland, Switzerland: IUCN/World Conservation Union, Occasional Paper of the IUCN Species Survival Commission Number 10, 1995).

69. cf. I. Stirling and A. E. Derocher, "Possible impacts of climatic warming on polar bears," *Arctic* 46: 240–245 (1993); and I. Stirling and N. J. Lunn, "Environmental fluctuations in arctic marine ecosystems as reflected by variability in reproduction of polar bears and ringed seals" in M. Young and S. Woodlin (editors), *Ecology of Arctic Environments* (Oxford: Blackwell Scientific Publications Ltd., 1997), pages 167–181.
70. I. Stirling, "The biological importance of polynyas in the Canadian Arctic," *Arctic* 33: 303–315 (1980); I. Stirling and H. Cleator (editors). *Polynyas in the Canadian Arctic* (Ottawa: Canadian Wildlife Service) Occastional Paper Number 45, 1981).
71. F. Symington, *Tuktu: A Question of Survival* (Ottawa: Canadian Wildlife Service, 1965).
72. Hoare and Clarke investigations are cited in J. P. Kelsall, *The Migratory Barren-ground Caribou of Canada* (Ottawa: Canadian Wildlife Service Monograph Series, Number 3, 1968).
73. A. W. F. Banfield, *Preliminary Investigations of the Barren-ground Caribou* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 1, Numbers 10A&B, 1951).
74. A. Loughrey, personal communication, interviewed at Ottawa, 26 November 1996.
75. Kelsall, *The Migratory Barren-ground Caribou.* (See note 72)
76. Kelsall, *The Migratory Barren-ground Caribou.* (See note 72)
77. Lewis, *Lively*, page 381. (See note 2)
78. D. A. Munro, personal communication, quoted in Lewis, *Lively*, page 383. (See note 2)
79. A. Loughrey, personal communication, interviewed at Ottawa, 26 November 1996.
80. Kelsall, *The Migratory Barren-ground Caribou.* (See note 72)
81. The team included Dr. Anton de Vos, biologist, Ontario Agricultural College; Dr. H. C. Gibbs, pathologist, CWS; Dr. J. S. Hart, physiologist, National Research Council; Dr. Olivier Heroux, physiologist, National Research Council; Ernie Kuyt, wildlife ecologist, Saskatchewan Game Branch; Alan G. Loughrey, wildlife biologist, CWS; Eoin H. McEwan, wildlife biologist, CWS; J. A. Mills, range officer, CWS; Dr. W. O. Pruitt Jr., biologist, Fairbanks, Alaska (contracted by CWS); Ed Ray, Superintendent, Michigan Conservation School; F. W. Terry, Game Management Officer, Saskatchewan Game Branch; Don Thomas, student assistant (CWS contract); and A. L. Wilk, biologist (CWS contract). Listed in Lewis, *Lively*, page 385. (See note 2)
82. Lewis, *Lively*, page 387. (See note 2)
83. Symington, *Tuktu.* (See note 71)
84. Kelsall, *The Migratory Barren-ground Caribou.* (See note 72)
85. Alan Loughrey notes in a letter to P. Logan dated 14 May 1998 that the trappers were Matt Murphy at Mulk-ox Lake, George Magrum at Aylmer Lake, Gus D'Aoust and Fred Riddle at Nicholson Lake on the Dubawnt River drainage, and two Eskimos at Eskimo Point and Baker Lake.
86. G. W. Scotter, *Effects of Forest Fires on the Winter Range of Barren-ground Caribou in Northern Saskatchewan* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 1, Number 18, 1964).
87. A. H. Macpherson, "Studies on the Manitoba-Keewatin barren-ground caribou herd" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967), page 44.
88. G. R. Parker, personal communication. (See note 44)
89. G. R. Parker, *Biology of the Kaminuriak Population of Barren-ground Caribou, Part 1* (Ottawa: Canadian Wildlife Service Report Series, Number 20, 1972), page 87.
90. G. R. Parker, *An Investigation of Caribou Range on Southampton Island, NWT* (Ottawa: Canadian Wildlife Service Report Series, Number 33, 1975).
91. T. Charles Dauphiné Jr., "The disappearance of caribou reintroduced to Cape Breton Highlands National Park," *The Canadian Field-Naturalist* 89(3): 299–310 (1975).
92. N. Novakowski, personal communication, April 1998.
93. G. W. Scotter, "How Andy Bahr led the great reindeer herd from western Alaska to the Mackenzie Delta," *Canadian Geographic* 97(2): 12–19 (1978).
94. G. W. Scotter, "Reindeer ranching in Canada," *Journal of Range Management* 25(3): 167–174 (1972).
95. D. C. Surrendi and E. A. DeBock, *Seasonal Distribution, Population Status and Behaviour of the Porcupine Caribou Herd* (prepared for Environmental-Social Program, Northern Pipeline Task Force on Northern Oil Development, by Canadian Wildlife Service, Western and Northern Region, Edmonton, 1976).
96. Don E. Russell, Art Martell, and Wendy A. C. Nixon, "Range ecology of the Porcupine caribou herd in Canada," *Rangifer*, Special Issue Number 8 (1993).
97. D. C. Thomas, *At the Crossroads of Caribou Management in Canada* (Ottawa: Canadian Nature Federation, Special Publication Number 10, 1981).
98. Donald C. Thomas and James Schaefer, "Wildlife co-management defined: the Beverly and Kaminuriak Caribou Management Board," *Rangifer*, Special Issue Number 7: 73–90 (1991).
99. G. R. Parker, D. C. Thomas, E. Broughton, and D. R. Gray, *Crashes of Muskox and Peary Caribou Populations in 1973-74 on the Parry Islands, Arctic Canada* (Ottawa: Canadian Wildlife Service Progress Notes Number 56, 1975).
100. J. S. Tener, *Queen Elizabeth Islands Game Survey 1961* (Ottawa: Canadian Wildlife Service Occasional Paper Number 4, 1963).
101. F. L. Miller, R. H. Russell, and A. Gunn, *Distribution, Movements, and Numbers of Peary Caribou and Muskoxen on Western Queen Elizabeth Islands, Northwest Territories, 1972–74* (Ottawa: Canadian Wildlife Service Report Series, Number 40, 1977).
102. Parker, personal communication. (See note 44)
103. Michael A. Ferguson and L. Gauthier, "Status and trends of *Rangifer tarandus* and *Ovibos moschatus* populations in Canada," *Rangifer* 12(3): 127–141 (1992).

1962–1967: Building a National Wildlife Program

Had an enquiring journalist asked Bill Mair, as Chief of CWS, to name the most significant CWS story of 1962, the answer might have come as a surprise. Drought on the prairies and the attendant drop in waterfowl productivity seemed highly newsworthy, as did the outbreak of anthrax among Bison at Wood Buffalo National Park. Alternatively, a reporter determined to grab headlines could choose to feature the danger of bird strikes to passenger aircraft or the presence of radioactive isotopes in venison, Caribou, and Moose meat.

Alarming though such items might be, however, it is entirely possible that Mair, a man with a keen sense of priorities and little patience for sensationalism, would have identified a less obvious example. CWS biometrician Denis Benson's collaboration with the Dominion Bureau of Statistics on an economic survey of wildlife use by Canadians was one of the truly significant projects of the year. Certainly it was the topic that the Minister of Northern Affairs and National Resources, the Honourable Walter Dinsdale, chose to highlight when he addressed the 27th Federal–Provincial Wildlife Conference in Ottawa in April 1963.

The study revealed that angling and hunting were chosen as recreational activities by more than 1.5 million Canadians over the age of 14, and that they spent at least $275 million annually in the pursuit of fish and game. The report estimated that about 345 000 people were hunters of waterfowl. The Minister put the numbers in perspective with a frank statement:

> The information gained by means of this survey will be of great value to us, and to those who administer provincial game departments, in obtaining the support we need if our wildlife management programs are to be in accordance with the needs. The results will also help us properly to allocate our resources with regard to the various sorts of wildlife for which we are responsible.
>
> The results of this survey help to some extent in placing the true value of wildlife in perspective, but, as you well know, this is only part of the story. The social and aesthetic values, which we have so far been unable to express in monetary terms, must not be forgotten.[1]

In other words, wildlife would be taken seriously by the politicians and policy-makers to the degree that wildlife agencies and managers could successfully demonstrate that their work generated economic benefits. Statistical and economic analysis could serve not only scientific ends, but strategic ones as well. Pursuing this line of reasoning, Mair himself noted an encouraging trend among wildlife specialists towards greater teamwork, more specialization, and increased interagency cooperation on policy-related issues. One of the issues to which he felt CWS was ready to respond was the role of wildlife management in the broader context of land use planning.[2]

The Agricultural Rehabilitation and Development initiative, launched in the previous year by the federal Department of Agriculture, provided an excellent framework for constructive alliances in support of the land use issue. Technological advances in agriculture, properly managed, could free huge amounts of marginal farmland for reversion to wildlife habitat. This was especially true in the prairies, where an urgent need to protect waterfowl habitat had been identified by the International Migratory Bird Committee. CWS therefore welcomed the opportunity that the Agricultural Rehabilitation and Development Act (ARDA) afforded to initiate research and pilot projects aimed at preserving prairie pothole wetlands. In 1963, CWS biologists Bill Miller in Manitoba and Herman Dirschl in Saskatchewan launched studies on prairie waterfowl habitat. That year, too, CWS entered into pilot lease agreements with 11 prairie farmers to protect 1184 pothole nesting sites against burning, cutting, or draining.

As it happened, the 1963 wildlife conference was the last over which Bill Mair presided. A few months later, having given more than 11 years of devoted leadership to CWS, he was appointed Chief of the National Parks Service. His successor as Chief of the Wildlife Service was David Munro, who had begun his CWS career as a summer student assistant in 1947.

As the Agricultural Rehabilitation and Development Act gained momentum throughout 1963, it became apparent that the general objective of rationalizing agricultural land would depend on rapid development of a comprehensive inventory of soil capabilities, not just for farming, but for forestry, wildlife management, and recreation as well. In outlining this task, L. E. Pratt, the first Chief of the Canada Land Inventory, issued an invitation "to wildlife biologists to work with the scientists in other fields concerned with major uses of our land."[3] And, indeed, a good many CWS biologists found themselves engaged in Canada Land Inventory-related projects over the next several years.

Meanwhile, work was progressing on other important fronts. In 1962, Rachel Carson's seminal book *Silent Spring* had served notice to the world that there was a high environmental price to be paid for the incautious use of pesticides. The concern was by no means new to CWS researchers (see Chapter 8). That same year, Vic Solman wrote a paper entitled "Biocides and Wildlife." In it, he cited a report to the International Association of Game, Fish, and Conservation Commissioners that demanded that the

The last national conference of CWS biologists was held in Ottawa in 1966. In attendance at the historic gathering were: (*front row, l. to r.*) E. McEwan, J. B. Gollop, F. G. Cooch, R. Jakimchuk, N. Perret, W. E. Stevens (Superintendent, Western Region), D. A. Munro (Director), A. G. Loughrey (Superintendent, Eastern Region), B. B. Virgo, T. C. Dauphiné, D. R. Flook, A. Radvanyi, L. P. E. Choquette, D. A. Benson, R. H. Kerbes; (*middle row*) R. W. Fyfe, J. A. Keith, A. Dzubin, J. Kerekes, N. Novakowski, V. D. Hawley, W. Morris, E. Kuyt, A. M. Pearson, F. H. Schultz, L. M. Tuck, F. L. Miller, T. Barry, G. E. Arsenault, G. H. Watson, J.-P. Cuerrier, G. Adams; (*back row*) J. B. Heppes, W. Thurlow, J. C. Ward, G. W. Scotter, R. H. Mackay, J. B. Millar, W. J. D. Stephen, W. R. Miller, A. H. Macpherson, W. T. Munro, R. Murray, R. D. Harris, J. P. Kelsall, B. C. Johnson, A. J. Erskine, C. A. Drolet, V. E. F. Solman (Photo credit: CWS).

onus be on the manufacturers to prove the safety of their products, and not on "the ecologist...[to] give proof that pesticides have damaging direct and indirect effects."[4]

In 1964, CWS contracted with C. David Fowle of York University to undertake the federal government's first detailed field study of biocides, collaborating with the New Brunswick Department of Lands and Mines to assess the impact on wildlife of phosphamidon, an early replacement for DDT in the struggle to control the Spruce Budworm. Serious negative effects on birds were reported.[5] That summer, too, CWS established a National Registry of Pesticide Residues in Wildlife Tissues. By 1967, a CWS pesticides group had been established that would, over the next 30 years, be responsible for major scientific contributions (see Chapter 8).

Habitat management, however, was the growth issue of the day. In its second year, the pilot program to lease prairie potholes expanded from 11 agreements to 50. The annual report of the Department of Northern Affairs and National Resources for 1964–1965 predicted confidently that by 1970, wetland habitat maintenance would be "the major item" in the CWS budget and identified preservation of 1.6 million hectares of prairie wetland "in their natural state" as a realistic goal.

This was not the sort of forecast to be made without solid backing at the highest level. In May 1965, the Honourable Arthur Laing emerged from a meeting of the Council of Resource Ministers in Victoria and announced a proposal for a National Wildlife Program (see Chapter 6). The principal features of his statement must have sounded familiar to CWS staff:

- positive steps to preserve waterfowl habitat through leasehold agreements and purchases;
- close collaboration between federal and provincial wildlife agencies; and
- the introduction of a federal migratory bird hunting licence to facilitate statistical surveys.

Six weeks later, at that year's wildlife conference in Winnipeg, the Minister expanded on the theme, outlining his vision of a Canada Wildlife Act as a means of providing a legal framework that would coordinate federal and provincial interests in wildlife as "an important basis for a variety of cultural and recreational pursuits." It would, he continued, tidy up a number of ad hoc arrangements, support "wildlife research of a general nature" in fields such as pesticides and pathology, and help Canada "live up to its end of the bargain implied by the Migratory Birds Convention Treaty."[6]

Successful policy initiatives grow from careful groundwork. It was not by coincidence that several other papers at the Winnipeg gathering addressed the link between land use and wildlife conservation. Eugene Bossenmaier, Chief of Game and Fur Management for the Manitoba Wildlife Branch, spoke on "Wildlife management in community pastures," Herman Dirschl of CWS discussed "Wildlife and multiple use of agricultural lands," and Arthur Benson, CWS land use specialist, presented a paper on "Wildlife and ARDA."

The National Wildlife Policy and Program was tabled in the House of Commons on 6 April 1966. The introduction stated that:

> ...the program to be developed under our general wildlife policy includes supporting and undertaking fundamental research in support of wildlife management throughout Canada, provision of information about wildlife, and co-operation with the provinces, on request and by agreement, in attaining the goals of wildlife management. The program also includes an increase in activities related to the federal responsibilities for migratory birds, wildlife in National Parks, and wildlife in the Northwest Territories.[7]

This was a ground-breaking statement of expanding federal intentions and the most substantial statement made in Parliament on the topic of wildlife since the passage of the Migratory Birds Convention Act in 1917. Its plans for research, the provision of information, and cooperation with provinces went beyond the existing parliamentary authority for migratory birds to include all wildlife. For species that cross provincial boundaries, such as Caribou, it transcended the established federal role in research to include management initiatives.

The policy had serious ambitions. The departmental annual report for 1965–1966 envisaged a 10-year prairie wetland preservation program, beginning in 1967, with an annual budget of $5 million. For the first five years, an additional $400 000 would be earmarked for wetland acquisitions elsewhere in Canada to protect breeding, staging, and wintering areas.[8] The latter amount enabled CWS to begin the process of land acquisition to create a system of National Wildlife Areas.

Once begun, the process of organizational growth continued. In keeping with the increased scope and scale of its responsibilities, CWS was elevated to the status of a separate branch of the department. A Prairie Migratory Bird Research Centre was planned, built, and opened in Saskatoon, headed by Bernie Gollop (see Chapter 3). Such expansion meant that the agency needed more biologists. Generous scholarships and summer research contracts were introduced to help top students prepare for careers in wildlife biology.

In the first year of the new policy (1966), 385 000 hunters purchased federal waterfowl hunting permits, lending credibility to the accuracy of the 1962 survey in the process.[9] The first National Harvest Survey was scheduled for 1967. Plans were announced to circulate questionnaires and to distribute envelopes to a sample of hunters with the request that they use them to return wings from the ducks they would shoot that fall (see Chapter 2). In preparation for a flood of data, CWS began recruiting specialists in surveys and statistics.

Public awareness and education had always been recognized as important but underfunded elements of the CWS strategy. Now, they received unprecedented support with the announcement that a new information and interpretation program would be based in interpretive centres representing key ecosystems across the country.

Canada's commitment to international tasks attained new levels during the mid-1960s, influenced in part, no doubt, by the interest of Prime Minister Lester B. Pearson. Expanding resources coincided with global opportunities, enabling several CWS personnel to participate in projects far from Canada. Herman Dirschl, for example, was assigned to the Canadian International Development Agency (CIDA) to conduct a study of vegetation in the Ngorongoro Conservation Area in Tanzania. Ward Stevens pursued ecological studies in Malaysia under the Colombo Plan, and Dick Brown was part of a research team that examined ocean currents and marine ecology off the coast of West Africa. John Tener and Louis Lemieux were also among the many whose participation in international projects during this period helped to earn and sustain a worldwide reputation for excellence on behalf of the Wildlife Service.

It was a period of heady growth. Four years earlier, in 1962–1963, CWS operations had cost the public purse a grand total of $932 390. In 1966–1967, as Canada embarked on the exhilarating celebration of the Centennial, the budget was over $2 million and climbing.

Notes

1. The Honourable Walter Dinsdale, "Welcoming address" in *Minutes and Papers of the 27th Federal–Provincial Wildlife Conference*, April 1963, Ottawa (Ottawa: Canadian Wildlife Service, 1963), page 2.
2. W. W. Mair, "Activities of the Canadian Wildlife Service" in *Minutes and Papers of the 27th Federal–Provincial Wildlife Conference*, April 1963, Ottawa (Ottawa: Canadian Wildlife Service, 1963), page 8. Already, Mair reported, CWS staff members Herman Dirschl, George Scotter, Donald Flook, and Donald Blood had been assigned to work on land use development and range management problems.
3. L.E. Pratt, "Wildlife and the Canada Land Inventory" in *Proceedings and Papers of the 28th Federal–*

Provincial Wildlife Conference, 18–19 June 1964, Charlottetown (Ottawa: Canadian Wildlife Service, 1964), page 77.
4. Victor E. F. Solman, "Biocides and wildlife" in *Minutes and Papers of the 27th Federal–Provincial Wildlife Conference*, April 1963, Ottawa (Ottawa: Canadian Wildlife Service, 1963), page 51.
5. C. D. Fowle, *Preliminary Report on the Effects of Phosphamidon on Bird Populations in New Brunswick* (Ottawa: Canadian Wildlife Service Occasional Paper Number 7, 1965).
6. The Honourable Arthur Laing, Minister of Northern Affairs and National Resources, "Wildlife is for people" in *Summary Notes and Papers of the 29th Federal-Provincial Wildlife Conference*, 18–19 June 1965, Winnipeg (Ottawa: Canadian Wildlife Service, 1965), page 61.
7. *National Wildlife Policy and Program*, House of Commons Debates, Wednesday, 6 April 1966, Appendix "A" (Ottawa: Queen's Printer, 1966).
8. Canada, Department of Northern Affairs and National Resources, *Annual Report Fiscal Year 1965–1966.*
9. Canada, Department of Indian Affairs and Northern Development, *Annual Report, 1966–67.*

CHAPTER 5. Working with Fish

Sustaining the Anglers' Paradise

From the time wildlife conservation became a matter of public policy in Canada, it was closely allied to the recreational pursuit of fish and game. Nowhere was this association more evident, for much of the 20th century, than in the management of lakes and streams in Canada's national parks with a view to providing sport for visiting anglers. Development was restricted in the parks. With a few exceptions, the hunting of birds and mammals was strictly prohibited. But game fish were perceived to be an exploitable resource and a powerful lure to tourists.

This fact was evident in the pursuit of an energetic program to stock selected waters with the desired species. In order to ensure an adequate supply of game fish, a fish hatchery was constructed at Banff as early as 1913. Two others followed in the late 1920s, at Waterton Lakes and Jasper national parks.[1] Thereafter, until the termination of the hatchery program in 1973, hundreds of thousands of fish were reared annually for release in park waters.

W. F. Lothian, in *A History of Canada's National Parks,* illustrates the scale of this activity by referring to one project in particular: the stocking of eastern Brook Trout in the Maligne River system. Brook Trout eggs were acquired from a hatchery in Pennsylvania and transported to the Jasper hatchery. Between 1928 and 1931, more than half a million fry were released in Maligne Lake. The site, previously barren of game fish, appears to have been highly suitable for stocking. The waters were opened to public angling in June 1932, and creel census data for 1933–1935 indicated that, during those years, 5616 Brook Trout were taken by angling from the previously unproductive Maligne River watershed.[2]

In retrospect, it seems fair to say that angling success and angler satisfaction were the chief criteria by which the fish culture and release program was judged during the 1920s and 1930s. When scientific expertise was required, it was sought from the Biological Board of Canada or the Department of Fisheries. Private consultants such as Donald Rawson, professor of biology at the University of Saskatchewan, were also called upon to conduct fish studies. It was not until 1940 that the Parks Service engaged a full-time limnologist, Harold Rogers. Unfortunately, his career was cut short when, about a year later, he was killed while serving in the Canadian forces overseas during the Second World War. He was not replaced until 1945, when Vic Solman was appointed to the vacant position.

One Man's Work

Vic Solman was eminently qualified for the role of Parks limnologist. A graduate of the University of Toronto, he had studied with J. R. Dymond and gained field experience during the summers of 1936–1938 at the newly established Ontario Fisheries Research Laboratory station in Algonquin Park.[3] Much of the emphasis there, as in the national parks, was on game fish, but Solman was also able to take a broader view of limnology through studies of plankton in freshwater lakes and streams. This work led to a Master's degree and, in the summer of 1939, to employment as a biologist with Ducks Unlimited.

The private waterfowl and wetland conservation organization was largely supported by American hunters and had only recently established a presence in Canada. As a limnologist, Solman found himself engaged in studying the impact of predation by Northern Pike on the survival of ducklings in the vast delta of the Saskatchewan River. Stomach content analysis of 3300 fish established solid evidence that predation by pike had a statistically significant, negative impact on duck production. The lack of a sustainable market demand for the predatory fish, however, meant that netting them for sale was not a financially viable means of controlling the problem. Fortunately, Solman's research also demonstrated a solution that was at once less costly and more effective than simply destroying the pike. It lay in providing alternative breeding habitat for the ducks by building pike-free impoundments to retain water in seasonal potholes and wetlands.[4]

Solman's work on the interaction between pike and ducks supplied him with the material for a successful Ph.D. thesis. In 1942, he left Ducks Unlimited (Canada) to work as a civilian meteorologist with the Royal Canadian Air Force. At the end of the war in Europe, he applied for a position as limnologist with the Parks Service, taking up his new duties on V-J Day, 9 August 1945.

The scope of the task left little opportunity for one person to accomplish much sophisticated limnological research in the early years. In an interview in November 1996, he recalled it this way:

> For the next three years I'd start off every spring in a half-ton panel truck with my equipment inside and a boat on top, and I'd run the circuit of the national parks from Cape Breton Highlands to Revelstoke. The hatcheries in Jasper, Banff, and Waterton were producing fish. The questions were: where to put them, and how many, and why. And then there were all the basic studies that hadn't yet been done by consultants. Don Rawson had done a lot of the work before, so Parks were relying heavily on his historical work and bringing the old system back up to speed again after a lapse of several years.[5]

It was soon evident that even the task of identifying appropriate locations for successful stocking was more than could reasonably be accomplished by one research scientist. Solman requested support and received it with the appointment of Jean-Paul Cuerrier. A professor at Université de Montréal, Cuerrier had been working for some years on the ecology of freshwater fish in the St. Lawrence watershed and had recently completed a Master's thesis on the Lake Sturgeon.[6] In July 1949, he left his teaching post to join the staff of CWS. Shortly thereafter, when Solman became Chief Biologist, Cuerrier succeeded him as senior limnologist.

Building a Program

Under Cuerrier's leadership, the limnology program grew. A need for more research and fieldwork through the 1950s led to the appointment of Clift Ward, Hugh Schultz, and Dudley R. Foskett. Schultz and Foskett moved on to other work, but by the mid-1960s the limnology team had been further augmented by the arrival of R. Stewart Anderson, Joseph J. (Joe) Kerekes, and Albertus H. (Bert) Kooyman.

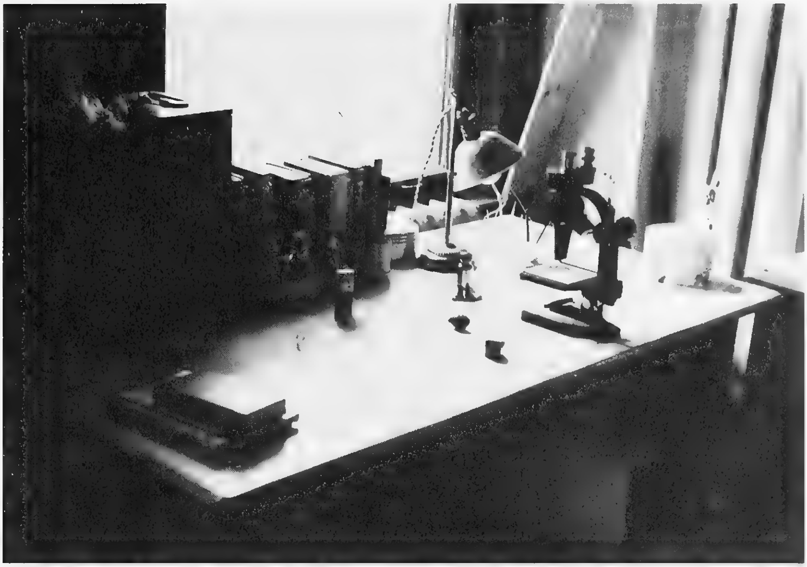
During the early 1950s, the Limnology Section was still primarily concerned with the management of sport fishing in national parks, along with control of mosquitoes and black flies, algae, and other problems that might disturb visitors' enjoyment of the 200 or more lakes and streams in Canada's 14 national parks.[7] Creel census data, derived from the voluntary return of survey cards by anglers, contributed to an approximate understanding of angling success and pressure throughout the park system and of the distribution and abundance of game fish species.[8]

As time passed, cumulative studies, not merely of angling results but of fish populations, water quality, and lake and stream ecology as well, provided an increasingly refined basis on which to make sport fishery management decisions. The work initiated by Donald Rawson in the 1930s and Solman in the 1940s was continued with vigour by their successors for the next 20 years and more. In addition to dealing with the administrative duties that accompanied the expansion of the Limnology Section, Jean-Paul Cuerrier pursued his own field research, concentrating his efforts on large bodies of water such as the Waterton Lakes[9] and Lake Minnewanka.[10] Clift Ward, Stewart Anderson, and David Donald extended the work of research and management to other waters in the Rocky Mountains parks. Dudley Foskett and, subsequently, Bert Kooyman did similar work in the Prairies, as did R. D. (Rolly) Wickstrom in the Yukon and Northwest Territories. Joe Kerekes conducted limnological surveys primarily in Atlantic Canada.

Once data on water quality, temperature, depth, pH levels, trophic status, nutrients, and existing flora and fauna had been assembled for a particular body of water, the limnologists had to determine whether modification of its ecosystem was advisable. Among the most overt forms of intervention was the treatment of lakes with poisons — primarily rotenone — to eliminate coarse fish species such as suckers that might compete with or prey upon trout. Cuerrier and Ward devoted considerable attention to this work during the 1950s and 1960s, carefully monitoring treated waters to assess the effectiveness of the toxicants and the duration of toxicity.[11]

A different type of direct intervention in aquatic habitats was aimed at improving the survival of fish in lakes where winter stagnation often resulted in a severe depletion of the supply of dissolved oxygen. In 1966, a summary report detailed a variety of imaginative methods that had been improvised to address this problem. In one case, a supply of fresh water was pumped into a small lake through a plastic pipe; in another, a fire pump was used to lift water through a hole in the ice and direct it across the surface of the ice and back into the lake about 30 metres away. The exposure to the air more than trebled the amount of dissolved oxygen in the immediate area, and the resident fish survived. Other techniques were also tried. One involved the use of an air compressor to pump air through a perforated, underwater plastic pipe. The constantly rising air bubbles increased the oxygen content of the water and maintained a current of warmer water that prevented the surface from freezing.[12]

Stocking or restocking waters with desirable fish species was another major component of the limnologists' work.[13] Early projects included the stocking of Clear Lake in Riding Mountain National Park with Walleye, the experimental introduction of Atlantic Salmon to Lake Minnewanka in Banff National Park, and the planting of Splake, a fertile cross between Lake Trout and Speckled Trout, in many locations. The Splake hybrid was the inspira-



The first CWS limnology lab, spartan in its simplicity, was established for limnologist Vic Solman in the fall of 1947, in the Norlite Building, Ottawa (Photo credit: V. Solman).

tion of Warden J. E. Stenton of Banff National Park, who experimented with cross-fertilization of the two species as early as 1946. A decade of additional work by Cuerrier at Banff and Jasper, and by others at the Ontario Fisheries Research Station and elsewhere, proved the viability of the new fish. Test releases indicated that the hybrids grew rapidly, rose aggressively to the angler's fly, and fought vigorously when hooked.[14] By the early 1950s, the Banff and Jasper hatcheries had produced sufficient numbers of second-generation hybrids to permit stocking of a number of lakes in the mountain parks with Splake.[15]

The demand for quality angling experiences was by no means limited to the Rocky Mountains parks. Fundy National Park had barely been established, in 1948, when Vic Solman made an initial limnological survey of the area and proposed that efforts be made to restore a spawning run of Atlantic Salmon to the Point Wolfe River. The river had been dammed more or less permanently for about 100 years, yet salmon still gathered in its estuary every spring, and, in those occasional years when high water or a breach in the dam permitted, the fish did not hesitate to migrate upstream. Solman recommended either construction of a fishway or removal of the dam.[16]

When Jean-Paul Cuerrier took up his duties with CWS in 1949, he reviewed the Point Wolfe River file and opted for removal. Instructions to this effect were issued to the Park Superintendent in April 1950, but when Cuerrier visited Fundy the following October, he was dismayed to find that nothing had been done. Without delay, he sent a telegram to Harrison Lewis seeking authorization for the project to proceed. The next morning, a Parks work crew took the first step by blasting a hole in the dam to drain the headpond. Cuerrier returned to Ottawa that afternoon, secure in the belief that the job would be completed in short order. However, for reasons unknown, it was left unfinished. Within 24 hours, a group of enterprising Beavers had plugged the hole.

That more or less set the tone for the next 30 years. From time to time plans would be prepared, either to remove the dam or to build a fishway, and then set aside.[17]

Only in the early 1980s, subsequent to Cuerrier's retirement from CWS, was a decision made to proceed once more with the salmon restoration project. A plan was approved and set in motion to plant 40 000 salmon fry per year, from 1982 to 1985, in the headwaters of the Point Wolfe River. In 1984, construction of a fishway was begun. The following winter, ice wrecked the partially completed structure, and in the spring of 1985, more than half the dam was removed, permitting salmon to ascend the river unimpeded at last.[18]

"Mother Nature finally took care of it," Cuerrier later observed. "But if I had just stayed at the site for another day or two back in 1950, it all would have been cleaned up 35 years earlier."[19]

Innovations

Working within the constraints of limited resources had a least one positive effect for the limnological section of CWS in the early years. It encouraged innovative thinking and constructive collaboration with other scientific agencies. A good illustration of this occurred in Banff National Park in 1952. One of the best locations for Lake Trout in the park was Lake Minnewanka, a narrow, sinuous body of water occupying a valley a few miles to the northeast of the town of Banff. Not long before, the water level of the lake had been dramatically increased by the operation of a hydro dam belonging to the Calgary Power Company. The change was so great that Cuerrier feared the fish might no longer be able to use their traditional spawning beds. The water was too deep and cold for divers to readily make visual inspections, yet that was the only way to determine the impact of the increased depth on spawning behaviour.

Cuerrier discussed the problem with Solman, who recalled having heard, a year or two previously, that the Radio and Electrical Engineering Division of the National Research Council of Canada (NRC) had been working on an underwater video camera. He made enquiries and found that, after one or two trial runs in a swimming pool, the device had been left sitting on a shelf at NRC ever since. When he approached its developers with the offer of a field test, they jumped at the chance.

Beneath the water, the camera was self-propelled and linked by a long cable to its operator, who could guide it in response to the changing image displayed on a small monitor. The clear mountain waters of Lake Minnewanka made it easy to discern plentiful supplies of newly laid Lake Trout eggs nestled among the stones on the lake bottom.

The success of this first-ever experiment in the use of television for fisheries research attracted considerable interest in the new medium, especially after CWS released the story to the press, giving full credit for the technological breakthrough to NRC. Cuerrier, Schultz, and Solman reported on the project in a paper presented to the Eighteenth North American Wildlife Conference,[20] and Solman wrote a popular article on the topic for the magazine *Forest and Outdoors*.[21]

Although video cameras never did win a lasting role as tools for the CWS Limnology Section, another, simpler instance of improvisation did lead to lasting practical application.

Stocking the waters of the western national parks commonly required that fish be moved over long distances, often in areas where pack horses were the only available means of transportation. Rigid metal tanks had long been used for this purpose but were poorly suited to the task. They were heavy, awkward to handle, and susceptible to overheating, and fish mortality between the hatchery and the release point was often high. Starting in 1958, Cuerrier and Ward began experimenting with alternative shipping containers. They found that a cylindrical plastic bag containing a surprisingly small quantity of water could hold as many as 400 fingerling trout or 150 yearlings when inflated with pure oxygen. Cardboard banana crates were sturdy and light and could accommodate several inflated bags of fish as well as an adequate supply of ice cubes to maintain a cool temperature.

With this method of packing, fingerling mortality rates fell dramatically.[22] One reason for the improved survival was that, on long trips, it was possible to reoxygenate the packages. Another benefit was that the smaller volume of water required resulted in less overall weight, enabling the horses to carry about three times as many fish per load as in the metal tanks.

The method proved to be extremely valuable for the transport of live fish by air as well. In 1958, Cuerrier and Ward reported on a successful transfer, via commercial aircraft and truck, from Laurentide Park north of Quebec City to Riding Mountain National Park in Manitoba, of 50 adult Brook Trout for use in the Splake breeding program. The fish travelled in three plastic bags packed in cardboard boxes. All were alive on arrival.[23]

Changing Priorities

Because efficient hatchery operations and procedures were vital to the success of the stocking program, the Limnology Section monitored everything from water quality and rearing methods to diet and the health of fish. In 1954, Jean-Paul Cuerrier undertook a major review of the hatcheries, at the end of which he proposed that the Waterton site be abandoned, except as a display and holding facility, and that the Banff operation be severely curtailed. Instead, he recommended that the Jasper hatchery become the chief source of fish for stocking programs in the region.[24] The following year, in a further review of hatchery operations, he compared the costs of running three separate facilities with the projected budget for a single hatchery at which all fish culture activities might be conducted.[25]

His reports generated no action for some time, although other events were occurring that lent them urgency. In 1955, an outbreak of disease at Waterton killed large numbers of young Rainbow and Cutthroat trout, and in 1956, the main hatchery at Banff had to be closed owing to the lack of a suitable water supply. Then, in 1959, a new source of water was secured at Jasper, assuring increased production capability for this facility. This, coupled with a consensus that had emerged from lengthy discussions both in Ottawa and in the field, led to Cuerrier's formulating the following specific recommendations: that the Waterton hatchery be closed; that the Banff hatchery be reduced to a minor, seasonal role; and that operations be consolidated at Jasper.[26] These recommendations were submitted to the Chief of the National Park Service in February 1960 and were implemented that summer.

Increased demands for Brook Trout eggs soon exceeded the productive capacity of the Jasper hatchery, and additional supplies had to be obtained outside the region. Unfortunately, disease appears to have been introduced to the hatchery along with some of the imported eggs. Losses of fry to a viral ailment known as infectious pancreatic necrosis began to mount in the mid- to late 1960s.[27] Studies undertaken between 1970 and 1972 by a variety of consultants pointed to the need for a new facility. The cost of replacement being judged too great, the Park Service announced the permanent closure of its last fish hatchery, effective 30 June 1973.[28] That decision effectively terminated a quarter century of intensive CWS involvement in fish culture.

Meanwhile, as early as the mid-1960s, the CWS limnology group had already begun broadening its interests from a perspective driven primarily by the concerns of recreational fisheries management to a more inclusive approach based on fundamental research. This was evident in Stewart Anderson's investigations of alpine and subalpine lakes. He had joined the CWS limnological team in 1966 and remained until 1979. He concentrated much of his early research on the limnology, productivity, and community structure of Snowflake Lake in Banff National Park, earning a Ph.D. from the University of Calgary for this work in 1968.[29] During a continued association with the university, he and his assistants surveyed the limnological features of over 400 lakes in the Rocky Mountain national parks.

In 1971, David B. Donald joined Anderson. As a team, they conducted extensive primary and secondary productivity studies of cold, high-altitude lakes. Anderson was a prolific scientific author with 25 publications in journals and 35 manuscript reports to his credit.[30] The reports and papers describing their work established a valuable bank of baseline data against which to compare the findings of future enquiries into the impact on these lakes of factors such as acidic deposition, global warming, deterioration of the ozone layer, and increased human traffic.

Bert Kooyman also joined CWS in 1966 and was assigned to manage fisheries and aquatic resources in Prince Albert and Riding Mountain national parks. His discovery of an unusual population of whitefish in the former location led to a Master of Science degree from the University of Calgary in 1970.[31] In the early 1970s, he undertook comprehensive limnological inventories of the two parks, as well as specific fisheries studies, including work on Goldeye in the Peace–Athabasca Delta and on Walleye in Prince Albert National Park. He continued to work in the prairie national parks until 1981. He then transferred to the Migratory Birds Section of CWS until his retirement in 1987. Another limnologist, Rolly Wickstrom, who had joined CWS in 1973 to work in Kluane and Nahanni national parks, succeeded Kooyman in the Prairie Region until 1991, when he joined the Ecological Conservation Branch of the Service.

Trading the academic setting of the Université de Montréal for a position as a CWS limnologist launched Jean-Paul Cuerrier, seen here at a field camp, on a career that spanned 32 years and took him to every province and territory of Canada to assess the condition of freshwater habitat for game fish (Photo credit: CWS).

The Last Limnologist

In Atlantic Canada, the shift towards pure limnology was actively encouraged by Jean-Paul Cuerrier's recruitment of Joe Kerekes in 1965. As a graduate student at the University of Alberta, Kerekes had become "indoctrinated" (his word) in the virtues of the Wildlife Service by former CWS biologist Bill Fuller, who was teaching a graduate seminar in wildlife management. In December 1965, while attending a conference in Montreal, the young limnologist was approached by John Tener.

> Tener told me that if I wanted a job I should call Jean-Paul Cuerrier in Ottawa. So I did, and the first question Jean-Paul asked me was whether I had any furniture that had to be moved. Well, a poor student just graduated sure didn't have furniture to worry about. That was in the good old days when there was expansion and people could make real decisions, just like that! The Park Service expected I would be another trout biologist, but the job title was limnologist, so I took it literally and practised limnology.[32]

Terra Nova National Park had been established only eight years prior to Kerekes' appointment, and he responded enthusiastically to the suggestion that he concentrate his efforts there. Starting in 1967, he began an inventory of all the water bodies in Terra Nova. Of those, he selected four for closer investigation of their productive capacity. This entailed monitoring the growth rates and feeding habits of Brook Trout and attempting, from this information, to estimate the total biomass and sustainable yield of these populations.

Up to this point, everything he had done was consistent with conventional park fisheries management. However, the next phase marked a departure into new territory, leading to a Ph.D. for Kerekes and a whole new dimension in limnological studies and environmental monitoring. As part of his analysis of the Terra Nova lakes, Kerekes had routinely measured total phosphorus and chlorophyll in water samples. He was struck by the correlation between the two and became one of the very first limnologists anywhere to appreciate the importance of phosphorus in the productivity of inland waters.

Kerekes' work attracted international attention. He was invited to participate in an Organisation for Economic Co-operation and Development (OECD) program on eutrophication, which involved studies of 128 lakes in 18 countries. In the late 1970s, he was seconded to OECD for two years to work as coauthor of a report on the work,[33] which would eventually play a key role in accomplishing the widespread banning of phosphate detergents.

During the 1970s, CWS undertook to complete comprehensive inventories of wildlife resources in Canada's national parks. Kerekes was assigned to coordinate the work on aquatic resources. Kejimkujik, in southwest Nova Scotia, was one of the first parks to be surveyed.[34] It was a fortunate choice. Most of the lakes in the park are naturally acidic, and Kerekes was intrigued by the question of how acidic deposition ("acid rain") would influence them. In 1977, he put forward a proposal to investigate the long-range transportation of air pollutants and their deposition in the Kejimkujik lakes.[35]

The international reputation accruing from his OECD experience probably aided the proposal's ultimate approval. Certainly, the initial reaction at CWS headquarters was less than enthusiastic.

> At first, people dismissed my proposal. I was told that I shouldn't study acid rain there because the amount was immeasurably small. Others said, "The acid is from organic sources, don't bother about it." I was even told that you couldn't study birds in Kejimkujik because the population density was too low. But I have to admit that I went and started working in a small way anyway. Eventually, in 1980, the proposal came to the attention of the national acid rain coordinating people and they liked it, so I was asked to do it officially. I worked on it then until 1983, when the Inland Waters Directorate came in with their own people to work on water quality.[36]

The study showed that highly sensitive, naturally acidic lakes such as the ones in Kejimkujik were affected even by minimal inputs of acid precipitation from distant sources. It was that sensitivity that won international recognition for the park as a very special site for the monitoring of environmental quality.[37] Thanks in large part to the acid rain study, the park eventually became the prototype site for Canada's national Environmental Monitoring and Assessment Network.

When the Inland Waters Directorate assumed an active role at the park, Kerekes turned to other tasks. He took part in the CWS Latin American Program, first in Brazil and later in Mexico, where he evaluated the productivity of lagoons and lakes in the states of Oaxaca and Chiapas. Only in 1988 did he return to the study of aquatic invertebrates, fish, and fish-eating birds in Kejimkujik.

In a sense, this brought him in a full circle, back to the early work in Terra Nova. Once again, he found himself looking at phosphorus as the determining key to the abundance of plankton, fish, and, by extension, fish-eating birds. The Kejimkujik findings were among topics highlighted in an international symposium on aquatic birds and limnology that he organized in Sackville, New Brunswick, in 1991.[38] The interest expressed at that event moved him to establish an international working group on aquatic birds, which has subsequently held workshops in Hungary and Yucatán.

Joe Kerekes retired in 1996, with an inescapable feeling that limnology in CWS had retired with him. In an interview in 1997 he reminisced:

> Back in the 1970s, Canada was on the cutting edge of limnology on a world-wide scale. If you came from Canada, people paid attention. Nowadays, it's neither here nor there. Today, it might be impossible to start the Keji [Kejimkujik] study. Of course, there's still water quality work going on, but that's not limnology. The fishery is one part of the lake. The water quality is another. It takes the holistic view of the limnologist to integrate them. But nowadays everyone is backing away from that generalized work. The federal departments say it's not in their mandate. The provinces say they have no money. And so a lot of good research in areas that are not clearly defined by legislation and regulation is just being abandoned.
>
> I was really lucky to be working when I did. I used to say, back then, "The good old days are happening right now." And I was right.[39]

Notes

1. W. F. Lothian, *A History of Canada's National Parks, Volume IV* (Ottawa: Parks Canada, 1981), pages 19–20.
2. Lothian, *A History, Volume IV*, page 21. (See note 1)
3. Vic Solman was supervised at the Ontario Fisheries Research Laboratory station by W. J. K. Harkness, to whom the lab on Lake Opeongo was later dedicated.
4. V. E. F. Solman, personal communication, interviewed at Ottawa, 26 November 1996.
5. Solman, personal communication. (See note 4)
6. J.-P. Cuerrier, *Observations sur l'esturgeon de lac* (Acipenser fulvescens *Raf.*) *dans la région du lac Saint-Pierre au cours de la période du frai* (Montréal: Université de Montréal, Thèse de maîtrise, 1949).

7. J.-P. Cuerrier, *Fisheries Management in Canada's National Parks* (Ottawa: Ottawa Field-Naturalists' Club Newsletter Number 10, 15 May 1951).
8. J.-P. Cuerrier, "An appraisal of creel censuses," paper presented to the Technical Session on Wetlands and Inland Water Resources of the 21st North American Wildlife Conference, New Orleans, Louisiana, 1956.
9. J.-P. Cuerrier and F. H. Schultz, *Studies of Lake Trout and Common Whitefish in Waterton Lakes National Park, Alberta* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 3, Number 5, 1957).
10. J.-P. Cuerrier, "The history of Lake Minnewanka with reference to the reaction of Lake Trout to artificial changes in environment," reprinted from *Canadian Fish Culturist* 15 April 1954 (Ottawa: Department of Fisheries of Canada, 1954).
11. J. C. Ward and J.-P. Cuerrier, "Use of fish toxicants in management of trout waters" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967).
12. J. Clifton Ward, Albertus H. Kooyman, and Jean-Paul Cuerrier, "Winterkill prevention" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967).
13. V. E. F. Solman, J.-P. Cuerrier, and W. C. Cable, "Why have fish hatcheries in Canada's national parks?" reprinted from *Transactions of the Seventeenth North American Wildlife Conference*, March 1952.
14. J.-P. Cuerrier, "This trout is a great fighter!" *Forest and Outdoors*, May 1954.
15. Lothian, *A History, Volume IV*, page 20. (See note 1)
16. V. E. F. Solman, *Limnological Investigations of Fundy (New Brunswick) National Park* (Ottawa: Canadian Wildlife Service Wildlife Management Bulletin Series 3, Number 2, 1950).
17. cf. J.-P. Cuerrier, *Rehabilitation of Atlantic Salmon in Point Wolfe River, Fundy National Park* (Ottawa: Canadian Sport Fishing Institute, 1982).
18. Rob Walker [former Chief of Interpretation, Fundy National Park], personal communication, 5 February 1998.
19. J.-P. Cuerrier, personal communication, April 1998.
20. J.-P. Cuerrier, F. H. Schultz, and V. E. F. Solman, "Underwater television in freshwater fisheries research" in *Transactions of the Eighteenth North American Wildlife Conference*, Technical Session Number 2, 9 March 1953, Washington, D.C.
21. V. E. F. Solman, "Television goes underwater," *Forest and Outdoors*, March 1953.
22. Canadian Wildlife Service, *Research Progress Report* (Ottawa: Department of Northern Affairs and Natural Resources, 1961).
23. J.-P. Cuerrier and W. C. Ward, "Alive, alive all!" *Intercom*, December 1958.
24. J.-P. Cuerrier, *Review of Fish Hatcheries in the Mountain National Parks*, 11 August 1954; cited in Lothian, *A History, Volume IV*, page 22. (See note 1)
25. Lothian, *A History, Volume IV*, page 22. (See note 1)
26. Lothian, *A History, Volume IV*, page 22. (See note 1)
27. Lothian, *A History, Volume IV*, page 22. (See note 1)
28. Lothian, *A History, Volume IV*, page 23. (See note 1)
29. R. S. Anderson, *Limnology of Snowflake Lake and Other High Altitude Lakes in Banff National Park* (Calgary: University of Calgary, doctoral thesis, 1968).
30. cf. R. S. Anderson and D. B. Donald, seven reports in the Canadian Wildlife Service Manuscript Report Series (Ottawa, 1977, 1978, 1979, 1980).
31. A. H. Kooyman, *Taxonomy of Whitefish in Waskesiu Lake, Saskatchewan* (Calgary: University of Calgary, M.Sc. thesis, 1970).
32. J. J. Kerekes, personal communication, interviewed at Dartmouth, Nova Scotia, 26 March 1997.
33. R. A. Vollenweider and J. J. Kerekes, *Synthesis Report. Cooperative Programme on Monitoring of Inland Waters (Eutrophication Control)* (report prepared on behalf of the Technical Bureau, Water Management Sector Group, Organisation for Economic Co-operation and Development, Paris, 1980).
34. Joseph J. Kerekes, "Aquatic research and long term monitoring in Atlantic Canada's National Parks" in J. H. Martin Willison, Søren Bondrup-Nielsen, Clifford Drysdale, Tom B. Herman, Neil W. P. Munro, and Tom L. Pollock (editors), *Science and the Management of Protected Areas: Proceedings of an International Conference*, held at Acadia University, Wolfville, Nova Scotia, 14–19 May 1991, organized by the Science and Protected Areas Association (Amsterdam: Elsevier Publishing, 1992).
35. Joseph J. Kerekes, *Long Range Transport of Air Pollutants — A Research Proposal* (Ottawa: Environment Canada, Canadian Wildlife Service, 1977; reprinted December 1994).
36. J. J. Kerekes, personal communication, 26 March 1997.
37. Kerekes, "Aquatic research." (See note 34)
38. Joseph J. Kerekes (editor), *Aquatic Birds in the Trophic Web of Lakes: Proceedings of a Symposium Held in Sackville, New Brunswick, Canada, in August 1991* (Dordrecht, The Netherlands: Kluwer Academic Publishers, 1994; reprinted from *Hydrobiologia* 279/280: 207–221, 1994).
39. Kerekes, personal communication. (See note 36)

1967–1972: Policy Implementation

The momentum imparted to the Wildlife Service by the implementation of the National Wildlife Policy and Program starting in 1966–1967 was evident in an expansion of staff and activities that extended to the end of the decade and beyond. Twenty years earlier, CWS had employed only nine biologists. Now, there were several times that many. Growth required management, and there was a corresponding increase in the number of supervisory positions throughout the organization. Thus, by 1967–1968, David Munro had been joined in the Director's Office by Deputy Director John Tener and by Hugh Schultz, Chief of Administrative Services. Other headquarters personnel with leadership responsibilities included Denis Benson

(Biometrics), Graham Cooch (Migratory Bird Populations), Darrell Eagles (Education and Information), Nick Novakowski (Mammalogy), Nolan G. Perret (Land Use), and Vic Solman (Migratory Bird Habitat).

At the regional level, the vagaries of the budget process had initially resulted in the Western Region's being fully funded and staffed some three or four years ahead of the Eastern. By the late 1960s, however, both had developed networks of research, conservation, and enforcement specialists, and parallel regional management structures had emerged, each headed by a Regional Superintendent. In 1968, Alan Loughrey headed the Eastern Region, whereas John Kelsall and then Ron Mackay filled in as Acting Superintendent of the Western Region while Ward Stevens was on a two-year assignment in Malaysia under the Colombo Plan.

The central theme of the National Wildlife Policy was habitat conservation. It was to be expected, then, that CWS acquisition of lands for National Wildlife Areas should accelerate across Canada. During 1968–1969 alone, 7280 hectares of wetland habitat were purchased in Saskatchewan, New Brunswick, Nova Scotia, and Quebec, nearly doubling the previously held total of 7550 hectares.[1]

The emphasis on purchasing land for wildlife areas represented a significant tactical adjustment from the original plan, which had identified the securement of millions of hectares of prairie wetlands by leasehold and easement as the primary goal. Two years into the program, David Munro was reporting to the 32nd Federal–Provincial Wildlife Conference, held on 9–11 July 1968, in Whitehorse, Yukon, that:

> Our experience in land acquisition has led us to a conclusion that some of you may already have reached, namely that the period from our decision to completion of the purchase of any multi-owner properties can rarely be expected to be less than two years and will more often be closer to three. Patience is a virtue.

and

> ...There is no doubt that our earlier definitions of goals for our "easement" program will have to be revised. Costs of land have risen so much that a re-appraisal is necessary.[2]

The cumulative burden of annual rental fees on a steadily increasing quantity of land was clearly going to be difficult to bear without severely curtailing other critically important activities. Therefore, the Prairie easement program gradually fell into disuse, while outright purchase of key sites became a focal point of habitat protection activity.

In 1969, David Munro left CWS to assume other senior responsibilities in the Department of Indian Affairs and Northern Development. His career path eventually led to a key position in international wildlife management as Director General of IUCN, a worldwide conservation agency headquartered in Switzerland.

Such a move inevitably had a ripple effect throughout the management ranks of CWS. Munro's successor as Director was John Tener. Alan Loughrey became Deputy Director, and Joe Bryant followed him as Regional Director (Eastern Region). In the west, some months later, Andrew Macpherson became Regional Director. These internal changes were minor, however, compared to the comprehensive rearrangement of Canada's environmental agencies that began in 1970.

The first step in this transformation severed the long-time connection between CWS and the Department of Indian Affairs and Northern Development. For the first time since 1918, Canada's wildlife management agency was no longer administered within the same department as its national parks service. Instead, in 1970–1971, CWS was moved, along with the Water Management Service and the Meteorological Service, and a new Environmental Quality Directorate, to the Department of Fisheries and Forestry. In June 1971, Royal Assent was granted to the Government Reorganization Act and triggered a further restructuring that led to the creation of Environment Canada. The mission of the new department was "to protect Canada's air, water, and land resources,"[3] and it incorporated the Fisheries Service, Water Management Service, Lands, Forests and Wildlife Service, Atmospheric Environment Service, and Environmental Protection Service. National Parks remained with Indian Affairs and Northern Development, but it was agreed that CWS would continue to exercise its advisory role on wildlife and ecological matters in the parks and in the Yukon and Northwest Territories.

As Director General of CWS, John Tener outlined the new grouping of environmental services in the following terms:

> The creation of the Department of the Environment, of which we are now a part, has already proved to be extremely beneficial to the service. The grouping of renewable resource agencies under the umbrella of environmental concern and action provides a framework for more effective participation of the service in assessing resource development problems as they relate to wildlife, and for participation in developing and maintaining environmental quality standards throughout Canada.
>
> The concept of the department is exciting; the problems are varied, immense, and complex, but the prospect of accepting the many challenges before us to achieve substantial progress in good resource management practices is stimulating and will, I am confident, be rewarding.[4]

Not surprisingly, the description of this regrouping of agencies preceded its complete implementation by a considerable margin. A year later, when the Federal–Provincial Wildlife Conference met in Dartmouth, Nova Scotia, Tener reported that final approval of the departmental restructuring was still pending.[5] The full implications of the change, in terms of internal reorganization of CWS, would not be realized for another three years.

Meanwhile, however, CWS continued to pursue the full range of established programs and activities and to undertake some new initiatives as well.

Conservation and management of migratory game birds throughout Canada (and mammals in the northern territories) continued to dominate the agenda. The creation of Environment Canada and the drafting of a Canada Wildlife Act during this period reflected a heightened public awareness of environmental and wildlife issues, from toxic contaminants to concern for endangered wildlife species and a growing demand that activities such as trapping, if permitted at all, should be carried out humanely. Research into seabirds, shorebirds, and forest songbirds became credible activities during these years, underlining the recognition that the CWS mandate extended to migratory nongame birds.

The work of the Pathology Section took on increased significance as outbreaks of anthrax necessitated the destruction of numerous Bison in Wood Buffalo National Park. In the field of communications, CWS produced several new "Hinterland Who's Who" clips and collaborated with the National Film Board on production of a conservation film entitled *Atonement*. Discussions were also begun on whether a film might be shot on the Whooping Crane and its struggle for survival. Tony Erskine's monograph on the Bufflehead[6] was published, and Les Tuck's work on snipes[7] was in press.

By 1972, the toxic chemicals and pesticides section that had been established in the mid-1960s was examining topics ranging from the impact of forest pesticide sprays on birds in Maritime forests to the accumulation of toxic substances in the tissues of fish-eating birds across Canada and of Polar Bears in the Arctic. In recognition of the potential for conflict between wildlife values and modern economic development activities, a new position, that of Bioeconomic Advisor, was created at CWS, and Denis Benson was named to fill it. This decision marked the beginning of an ongoing CWS interest in developing methods for assessing the involvement of Canadians in nonconsumptive and recreational uses of wildlife.

Canada Land Inventory surveys had largely been completed by the end of this period. More than 100 wildlife capability maps at a 1: 250 000 scale had been published, with a further 275 in preparation. The value of this type of inventory work became increasingly evident in the face of development projects ranging from wetland losses in the St. Lawrence Valley to the assessments of the James Bay power development scheme and Arctic oil and gas exploration proposals. CWS found itself increasingly drawn into evaluating the environmental impact of such undertakings. What to do about oil spills at sea and on land was another current topic, as was the somewhat related subject of the environmental impact of the proposed Mackenzie Valley Pipeline.

On the international front, it was during this period that the International Biological Programme was brought to life in Canada. Several CWS scientists played prominent roles in this exercise, especially with regard to developing an extensive inventory of candidate sites for protection of wildlife habitat.[8] CWS was also involved in negotiations that would eventually culminate in the signing and ratification of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and discussions of the responsibilities of circumpolar nations with regard to Polar Bears.

The range of concerns to which CWS was expected to respond had broadened considerably over the span of its first 25 years and showed every sign of continuing to do so. John Tener summed it up in this rather prophetic fashion:

> No organization can afford to be static or complacent in its attitudes and performance. In our field particularly, the growing public concern about the Canadian environment in general and about wildlife in particular, the burgeoning use of outdoor recreation to occupy leisure time, and the increasing strength of citizens' organizations able to articulate their views on a wide array of issues of direct interest to us all demand that we collectively, as individuals, and as organizations, be sensitive to public views and respond effectively and responsibly.[9]

Those factors would play an increasingly important role in the evolution of CWS over the next quarter century.

Notes

1. Department of Indian Affairs and Northern Development, *Annual Report: Fiscal Year 1968–1969* (Ottawa: Queen's Printer, 1970), page 17.
2. David A. Munro, "Report of the Director of the Canadian Wildlife Service" in *Transactions of the 32nd Federal–Provincial Wildlife Conference, 9–11 July 1968, Whitehorse, Yukon* (Ottawa: Canadian Wildlife Service, 1968), pages 6–7.
3. Environment Canada, "Foreword" in *Annual Report of the Fiscal Year Ending March 31, 1972* (Ottawa: Information Canada, 1972).
4. J. S. Tener, "Report of the Canadian Wildlife Service" in *Transactions of the 35th Federal–Provincial Wildlife Conference, 6–8 July 1971, Toronto* (Ottawa: Canadian Wildlife Service, 1972), page 13.
5. J. S. Tener, "Report of the Canadian Wildlife Service" in *Transactions of the 36th Federal–Provincial Wildlife Conference, 11–14 July 1972, Dartmouth, Nova Scotia* (Ottawa: Canadian Wildlife Service, 1972), page 17.
6. A. J. Erskine, *Buffleheads* (Ottawa: Canadian Wildlife Service Monograph Series, Number 4, 1972).
7. L. M. Tuck, *The Snipes; A Study of the Genus* Capella (Ottawa: Canadian Wildlife Service Monograph Series, Number 5, 1972).
8. A good example of work initiated under the International Biological Programme is found in D. N. Nettleship and P. A. Smith, *Ecological Sites in Northern Canada* (Ottawa: Canadian Committee for the International Biological Programme, 1975).
9. Tener, "Report" in *Transactions of the 36th Conference*, page 2. (See note 5)

CHAPTER 6. Habitat Programs: Protecting Space for Wildlife

Ecologists of the late 1990s generally presume the link between wildlife and habitat to be axiomatic. Without habitat — i.e., adequate and appropriate conditions in which to feed, breed, and find shelter — no species can survive and prosper. Consequently, the securement and protection of wildlife habitat are a major preoccupation of wildlife management agencies. It has not always been so.

In 1947, when the Government of Canada created the Dominion Wildlife Service to administer the provisions of the Migratory Birds Convention Act, it did not emphasize habitat protection as an essential element of that task. Holistic ecology may have been a topic of interest among academic theorists and a source of fascination to some waterfowl biologists in the field. During the 1950s, Graham Cooch in the Arctic, Charles Bartlett and Joe Boyer in the Maritimes, and James and David Munro on the west coast — to name but a few — were all documenting the importance of habitat to species survival. In practice, however, most wildlife managers focused their efforts on protecting preferred species and controlling the harvest. Open and closed seasons, bag limits, predator control, and an unrelenting campaign against poaching were the chief tools of the conservation trade.

Migratory Bird Sanctuaries

In fact, the Act did set out criteria for the establishment of Migratory Bird Sanctuaries. This status could be granted to locations where important concentrations of migratory birds gathered for part of the year, especially if the habitat in question were vulnerable to human disturbance. Within these sanctuaries, the regulations prohibited hunting, egging, destruction of nests, or possession of firearms and forbade dogs and cats from running at large while the birds were present. In some sanctuaries, primarily those of the Maritimes and the Quebec North Shore, the rules were enforced by seasonal wardens who patrolled during critical parts of the year to diminish the toll of illegal slaughter.

The seabird colonies of Percé and Bonaventure Island off the Gaspé Peninsula and Bird Rocks in the Magdalen Islands were the first sites to gain sanctuary status under this authority, in 1919. Ten more seabird nesting locations, on islands along the north shore of the St. Lawrence between Sept-Îles and the Strait of Belle Isle, were added in 1925 at the urging of Harrison Lewis. Robie Tufts succeeded in securing a 250-hectare sanctuary on Grand Manan, in the Bay of Fundy, in 1931, and nearby Machias Seal Island with its large colonies of Arctic Terns and Atlantic Puffins was added to the list in 1944.

Sites were set aside elsewhere across Canada as well. In 1947, the newly created Dominion Wildlife Service inherited responsibility for a total of 67 Migratory Bird Sanctuaries and 27 special game officers who were employed to supervise them. The next few years saw the number of sites increase. By 1952, there were 88 of them, covering a total area of 4680 square kilometres.[1]

Not all the sanctuaries were as important as those in the Gulf of St. Lawrence and the Bay of Fundy. Technically they existed, and still exist, to protect species rather than habitat. In cases where the land is privately owned, the choice of whether to maintain suitable habitat conditions can depend on the good will of the owner.

Sanctuary status was not necessarily granted in perpetuity. A golf course in Kentville, Nova Scotia, for example, enjoyed the distinction of being listed among Canada's Migratory Bird Sanctuaries in 1943. A review of its status 20 years later found it to have no significant value for birds. Its delisting in 1963 suggests that the original designation may have reflected political, rather than conservation, priorities. Regardless of occasional oddities like these, the total number of legitimate Migratory Bird Sanctuaries grew steadily, and the area encompassed by them grew enormously. Arctic field research by pioneering individuals such as Dewey Soper, Tom Manning, Graham Cooch, Tom Barry, and other discoverers of key nesting grounds for waterfowl led to the far-sighted creation of huge sanctuaries on Banks Island, Bylot Island, and the Queen Maud Gulf, to name but three of many protected Arctic sites (see 1957–1962, endnote 1). With a surface area of 6.2 million hectares (or 62 000 square kilometres), the Queen Maud Gulf sanctuary is larger than all the rest of Canada's Migratory Bird Sanctuaries put together.[2]

CWS and the Canada Land Inventory

Although habitat was not the object of a formal program in the early years, exploratory population studies undertaken by CWS wildlife biologists contributed to the accumulation of a large body of knowledge about the places where wildlife lived. The condition of wetlands, the productivity of salt marshes, the growth of lichens on the Arctic barrens: such factors could be critical to reproductive success and the health and density of populations. Canada's guardians of waterfowl, seabirds, and Arctic mammals monitored them closely. For example, when Joe Boyer was assigned as wildlife officer for the Maritimes, he was impressed by the importance to waterfowl of the Tantramar Marshes on the Isthmus of Chignecto. He worked for most of a year in a vain effort to forestall plans for draining a large section of the fertile wetland under the provisions of the Maritime Marshland Reclamation Administration.

Despite his failure, the same land was acquired by CWS a generation later and reflooded as part of the Tintamarre National Wildlife Area.[3]

It was really in the 1960s, however, that the Wildlife Service began to commit significant resources to the study of habitat management as a conservation tool. In 1961, biologist W. Arthur (Art) Benson undertook an ecological study of the extensive salt marshes of the lower mainland coast of British Columbia, critically important wintering habitat for tens of thousands of waterfowl. The following year, Joe Bryant began assessing the significance to waterfowl of more than 22 000 hectares of privately owned freshwater marshes along the Ontario shores of Lake Erie and Lake St. Clair. Simultaneously, Herman J. Dirschl was developing an integrated plan for use of lands in and adjacent to the sanctuary at Last Mountain Lake, Saskatchewan.[4] A cooperative study led to a proposal that, where wildlife potential exceeded agricultural potential within the study area, wildlife management would take precedence.[5] Dirschl also conducted a broad habitat study across 4100 square kilometres of the Saskatchewan River Delta[6] and later undertook extensive work on the ecology of the Peace–Athabasca Delta.[7] Bill Miller was project leader of a similar assessment of the Delta Marsh complex[8] around the south end of Lake Manitoba. Both projects led to recommendations for land use that emphasized waterfowl needs ahead of other wildlife and agriculture. Smaller areas of prairie wetland were the primary focus of John B. Millar, the CWS participant in a cooperative, long-term study to determine the factors affecting these "potholes" and their importance to water conservation and waterfowl productivity.[9]

The passage of the Agricultural Rehabilitation and Development Act (ARDA) in 1962 accelerated the appreciation of habitat as a critical element in wildlife conservation and management. Aimed at rationalizing Canada's agriculture industry, the new legislation encouraged not only the consolidation of small farms into larger, more viable economic units, but also the reversion of submarginal farms to "natural" habitat. To accomplish this goal required an assessment of the land use capability of vast portions of rural Canada, in a project called the Canada Land Inventory.

By the time it was completed, in 1969, the Canada Land Inventory had gathered and presented capability data for nearly 2.6 million square kilometres, largely in the settled regions of southern Canada. In all, the area was represented on 196 map sheets at a scale of 1: 250 000. Federal and provincial agencies pooled resources and abilities to gather and evaluate data relating to such varied land uses as farming, forestry, recreation, and the production of hoofed mammals, waterfowl, and game fish. Specialists in the selected disciplines developed capability assessment techniques that enabled them to allocate values from 1 (best) to 7 (worst) for each unit of land or water.

To classify the suitability of land for hoofed mammals, field teams gathered information on factors such as availability and quality of food and protective cover. Subclasses indicated climatic and soil conditions that could affect wildlife productivity. Maps for waterfowl capability presented a somewhat more complex challenge, in view of the migratory nature of the birds in question. Not only breeding habitat, but staging, wintering, and resting areas had to be included.

The process of surveying and mapping began in 1965. A review of aerial photographs and geological surveys provided basic landform information, which was then augmented by ground studies and low-level aerial inspection. The provincial wildlife agencies carried out the work on hoofed mammals, in keeping with their jurisdictional responsibilities. CWS conducted the waterfowl capability mapping in all provinces with the exception of Prince Edward Island. In Newfoundland, CWS collaborated with provincial officials to conduct a waterfowl inventory, but not according to the methodology adopted for the Canada Land Inventory.

Canada Land Inventory activities involved a wide range of CWS personnel between 1965 and 1970. The role of national coordinator of the wildlife sector of the undertaking was successively filled by Art Benson, who subsequently went on to head the Canada Land Inventory, Nolan Perret, and Vic Solman. George Watson served as eastern regional coordinator, while Ron Jakimchuk and Gordon Staines both coordinated regional activity in western Canada. On the ground, Darrell Dennis, Paul Dean, and Al Doberstein worked full time on waterfowl habitat classification in the Maritimes. Charles Drolet started the project in Quebec, where he was first assisted and then succeeded by George Arsenault. In Ontario, the project was headed by Bruce Johnson, and in Manitoba, by Glen D. Adams. Harold Weaver headed the Canada Land Inventory wildlife team in Alberta, and the challenging task of mapping wildlife capability in British Columbia's mountainous terrain fell to Ernest W. Taylor and J. F. T. (Joe) Carreiro.[10]

The data compiled in the course of the Canada Land Inventory mapping exercise constituted a coherent body of information on wildlife habitat that far exceeded anything hitherto available in Canada. It was widely used as an authoritative source for decision-making and projecting wildlife management strategies. In the 1970s, engineers and planners made important use of the database to develop geographic information system overlays in order to identify potential conflicts in land use.

In more recent years, CWS has participated in additional wetlands inventory projects to gather updated information on many key areas of waterfowl production. In the Atlantic Region, for example, the Maritime Wetland Inventory (1980–1988) documented all wetlands greater than 0.25 hectare in size. Maps and data from this undertaking are still widely used by consulting firms, such as those engaged in planning possible routes for a pipeline to carry natural gas from Sable Island across mainland Nova Scotia and New Brunswick. Other regions have participated in similar projects, although none since the Canada Land Inventory has attempted to establish a uniform national classification system. One valuable result of this work has been to give people information tools that enable them to make informed decisions about the use of wetlands, in part by seeking to achieve optimal economic benefit through minimal environmental cost.

Another result of CWS involvement in the Canada Land Inventory was the accumulation of a body of expertise in the field of environmental assessment. The Canada Land Inventory process had revealed many instances where land was being used inappropriately, relative to its highest capability. Clearly, in matters relating to land use, the dictates of economic opportunity did not always coincide with the best environmental practices. There was a demonstrable need to gather and analyze data that would enable governments to mediate between competing desires to exploit or conserve the environment. The Canada Land Inventory experience had fitted CWS especially well to perform this function with regard to wildlife and wildlife habitat considerations.[11]

Some of the first environmental assessment undertakings in which CWS became involved focused on the 1.8 million square kilometre Mackenzie River Basin. Many aboriginal residents of the area were still largely dependent on Caribou, waterfowl, and fish for food and on the trapping of Muskrats and other furbearers for cash income. Would pipelines or highways disrupt traditional Caribou migration routes? Would river diversions or power dams have a negative impact on Muskrat and waterfowl habitat? Would bridge construction cause silt to foul fish spawning beds? These were questions for biologists familiar with the behaviour and habitat requirements of the species in question, and that often meant CWS biologists. Over the next 30 years, they were found, not just in the Mackenzie Basin, but across Canada, endeavouring to determine whether proposed environmental changes would do serious or permanent harm to wildlife (see Chapter 3). They assessed the risks inherent in proposals for hydroelectric projects, offshore oil and gas developments such as Hibernia and Sable Island, and infrastructure developments such as the link between Prince Edward Island and the mainland, and they performed a host of smaller project reviews and referrals annually. Even CWS activities became subject to review. Each region eventually had its own environmental assessment specialists, and environmental assessment guidelines were developed and published.[12]

Habitat Management

The increased attention that the Agricultural Rehabilitation and Development Act brought to bear on agricultural land use led CWS to become involved in other habitat-related initiatives besides the Canada Land Inventory. It underlined the considerable threat posed to wildlife by alteration of the landscape. Mechanization, farm consolidation, and growing markets for grain were among factors that were encouraging farmers to drain prairie sloughs or potholes as one way of increasing the efficiency of their operations. The trend was disturbing to wildlife managers in both Canada and the United States, as pothole marshes accounted for a significant portion of the annual production of ducks for the central flyway.

Starting in 1963, CWS had begun leasing small wetlands from farmers, specifically in order to ensure their availability as breeding habitat. The pilot project began with fewer than a dozen 10- and 20-year leases under which farmers agreed not to drain or fill the wetlands in question, nor to burn the surrounding marsh vegetation for the duration of the agreement. The pothole leasing program grew rapidly and took on a broader, national role when the then Minister, the Honourable Arthur Laing, tabled a National Wildlife Policy and Program in the House of Commons in April 1966 (see Chapter 10). With regard to the maintenance and management of migratory bird habitat, Mr. Laing outlined a seven-point plan, presented here in a somewhat abridged form:

1. Survival of migratory birds is dependent upon maintenance of habitat. Suitable wetland habitat in amounts sufficient to support desired populations of ducks and geese will be preserved by acquisition, lease, or other form of agreement.
2. Agreements may be concluded with provinces desiring to participate in acquisition or management of habitat….
3. …when it is economically feasible, habitat will be improved so as to increase its carrying capacity for and productivity of birds. This may be done by controlling water levels, altering natural plant cover, and creating nesting and resting sites.
4. Habitat may be managed so as to influence the local distribution of birds and thus reduce the possibility and extent of damage to agricultural crops and other interests. Management plans...where significant damage by birds occurs or may occur will include features designed to eliminate or minimize damage….
5. Land managed for migratory birds should be available for public use so far as possible...[but] will involve controlling public activity so that it does not damage the habitat or undesirably disturb the birds….

In the coastal wetlands of Quebec's James Bay coast at certain times of the year, the swarms of biting insects become so numerous that even CWS biologists — in this case Léo-Guy de Repentigny and Gilles Chapdelaine doing a vegetation survey in 1972 — have no choice but to adopt protective gear (Photo credit: L.-G. de Repentigny).

6. Land secured primarily for preservation of migratory bird habitat may be used for other productive purposes if they are not incompatible….
7. Two programs to acquire adequate control of wetland habitat are planned.
   a) Agreements...whereby [landowners] agree not to drain or fill the wetlands which they own, or burn the vegetation around them, in return for a payment based on the value of the surrounding land discounted at five per cent for a 20-year period. This procedure [should] maintain about two-thirds of the more than six million small potholes in the vitally important prairie breeding grounds.
   b) Purchase or long-term lease of large marshes which require management for greater productivity and public use. Large marshes are important not only as breeding areas, but also as areas where the birds may winter or rest during migration. They are also the areas where much of the hunting takes place....The magnitude of a program to preserve all such areas, and the priorities for acquisition, cannot be finally determined until the ARDA-sponsored Land Capability Inventory, now under way, is completed and studied.[13]

For the first time, the full weight of the Government of Canada was unequivocally committed to wildlife habitat conservation and, moreover, to funding a program in which direct acquisition and management of land would play an important part. Initially, it was forecast that as much as $5 million would be spent annually to lease up to 1.6 million hectares of wetlands from prairie farmers. This generous level of funding was never to be realized. Following the policy statement of 1966, however, $1.2 million annually was assigned to CWS for purposes of habitat protection, and by the end of fiscal year 1968–1969, leasehold agreements were in place covering 25 000 hectares of prairie pothole wetlands. In addition, an agreement was signed with the Lower Kootenay Band Council to preserve 1300 hectares of reserve lands near Creston, British Columbia.[14]

The study of prairie wetland habitat gained further momentum with the establishment of the CWS Prairie Migratory Bird Research Centre in Saskatoon. To mark its opening, the Wildlife Service sponsored a seminar on prairie wetlands from 20 to 22 February 1967. For three days, delegates from Canada and the United States considered the number, size, permanence, hydrology, chemistry, vegetation, value to waterfowl and agriculture, legal status, ownership, and future prospects of prairie potholes. As Harrison Lewis wryly observed, the topic was discussed "as far as the available data would allow, or even further."[15]

Although protection of the "prairie duck factory" occupied the spotlight during the 1960s, it was only one of several aspects of wetland conservation that developed under the aegis of the National Wildlife Policy. Over the next decade, in fact, the prairie leasing project faded somewhat from view, and the outright purchase of critical sites became an increasingly important strategy.

Technically, the authority to designate lands as National Wildlife Areas would not be granted until after the passage of the Canada Wildlife Act (1973) and the proclamation of Regulations in 1977. Nonetheless, the policy declaration was sufficient to launch CWS in the real estate business. Two properties in Nova Scotia — Sand Pond, in Yarmouth County, and the John Lusby Saltmarsh near the border town of Amherst — were among the first acquisitions, in 1966–1967, as was a tract of 5920 hectares at Last Mountain Lake, Saskatchewan. Other early acquisitions included lands at Cap Tourmente, Quebec, and the Tintamarre National Wildlife Area in New Brunswick on the Isthmus of Chignecto.

Sometimes, the merits of candidate sites for National Wildlife Area status were easy to demonstrate. On other occasions, creativity and even personal influence might play a part. In the Atlantic Region, one location that had strong support from habitat biologist Alan D. (Al) Smith was East Island, near Grande Entrée in Quebec's Magdalen Islands. In 1968, Smith wrote up a proposal to acquire the property, but, although it was deemed interesting, it failed to win the necessary support in Ottawa. Two years later, in 1970, author Farley Mowat moved his household from Burgeo, on the south coast of Newfoundland, to Grande Entrée. A year after that, an old friend of Mowat's, Robert Shaw, became Deputy Minister of Environment Canada, and Mowat contacted him to recommend protection for East Island. Shaw called John Tener (Director General at the time), Tener called Nolan Perret (head of the habitat program), and Perret called Al Smith to enquire about the site. In Smith's words:

> We dusted off my old [1968] report and checked it over. Within a week it was on Bob Shaw's desk. Then he came down to have a look himself. I met him and his executive assistant at the Charlottetown Airport and we flew on to meet with Farley Mowat and have a look at the area. We walked around it, and drank some black rum with Farley, and came back..., and the Treasury Board submission went through so fast that we were in the land purchase mode for East Island National Wildlife Area within three months, where often it can take as much as 6 or 7 years to get that far.[16]

A second story relates the sometimes convoluted way that approvals for purchase could be sought. The Vaseux-Bighorn National Wildlife Area, at the southern end of the Okanagan Valley in central British Columbia, had been proposed on the strength of its value as wintering habitat for Bighorn Sheep, which regularly descend to the valley to graze. In Ottawa, however, Nolan Perret recognized that Treasury Board might not approve funding for CWS to acquire the land if no migratory birds were involved. He sent an urgent query westward: "Can't you find a migratory bird in there somewhere?" As it happened, the location was a favoured nesting area for the Canyon Wren, a desert bird whose range barely reaches into southern British Columbia.[17] On receipt of this information, Perret was able to guide the project past the remaining bureaucratic hurdles, and an entire ecosystem won protection thanks to the presence of one uncommon species.

During this period, other habitat types besides wetlands gained recognition for their importance to wildlife. Much of the habitat assessment of forest and upland ecosystems occurred in national parks (see Chapter 4). One exception to this was the sandhill complex along the eastern boundary of the Suffield Military Reserve in southeastern Alberta. In the early 1970s, Ward Stevens made a preliminary inventory of this locale on behalf of CWS, and it was designated as an environmentally critical area.[18] Shortly after that, the Prairie Farm Rehabilitation Administration entered into negotiations with the military authorities, and by 1977, cattle were grazing on a portion of the dry grasslands of the reserve adjoining the South Saskatchewan River. In 1986, Len Shandruk put forward a proposal that the land be set aside as a National Wildlife Area. Despite some initial reluctance, the Department of National Defence signed a memorandum of agreement on this subject in 1992. Two years later, Garry C. Trottier led CWS's multidisciplinary baseline inventory of wildlife in the district, confirming its importance as habitat for a number of rare, threatened, and endangered prairie wildlife species, including Short-horned Lizard, Burrowing Owl, and Ferruginous Hawk. Brenda Dale, who led the avifauna team, recalls how satisfying and exciting the survey work was. Although all the team members had worked in grasslands before, it had always been on damaged ecosystems — too small, too fragmented, too disturbed by human activities to function properly. Suffield, however, was a large, intact, fully functioning ecosystem with enough variety in topography and management to provide habitat for the complete range of grassland species, and in impressive numbers.[19] At the time of writing, it was expected that a 540-square-kilometre area would be gazetted as a National Wildlife Area.

Acquiring land was by no means the only activity of the CWS habitat program in the 1970s. Once acquired, National Wildlife Areas, as well as other conservation lands secured under a variety of joint agreements, underwent an ecological inventory process. Working under the direction of a designated habitat biologist, technicians and summer students tested water quality, identified plants and invertebrates, surveyed populations, and generally developed a database on each new property.

As the designated habitat biologist for Saskatchewan, Philip S. (Phil) Taylor took into account the needs of plants, all types of birds,

While still students in the mid-1960s, Al Smith and Bill Prescott assisted John Kelsall in studies of snow ecology. Here, Prescott prepares to take a sample at Fundy National Park, while Smith takes notes on the procedure (Photo credit: John Kelsall).

mammals, insects, and even fish, in the days when most habitat management practices were designed to benefit only game birds. Starting in the late 1970s, long before "biodiversity" became a common term, he took a closer look at the traditional habitat management techniques in use on Migratory Bird Sanctuaries and National Wildlife Areas, particularly at Last Mountain Lake. He began studies into how grazing, burning, and hay management affected songbirds and how water-level manipulation of water basins affected shorebirds, and then he used the results of these studies to guide management activities so that several species could benefit. His interest in maintaining the biological integrity of the lands in his care led him to use controlled burning and grazing to halt the spread of exotic grasses that had invaded Last Mountain Lake to the detriment of the Sprague's Pipit and Baird's Sparrow. This success inspired another effort to stimulate the health of native plants, the Prairie Restoration Project, in which native seeds were collected and planted. The techniques developed in that program are in use throughout Saskatchewan.

Ducks Unlimited (Canada), already active in habitat protection and enhancement on its own considerable holdings across Canada, became an active partner at many National Wildlife Area sites, contributing engineering know-how and expertise in the design and construction of freshwater marsh impoundments to enhance nesting habitat for waterfowl. In the Maritimes, this strategic alliance turned out to be particularly productive. There, starting in 1968, CWS habitat biologist William R. (Bill) Whitman developed a model for preimpoundment feasibility studies to assess habitat potential in terms of a range of practical factors, such as fertility, soil permeability, and actual use by birds.[20]

By 1976, 10 years after the acquisition program began, CWS had secured a total of 34 National Wildlife Areas comprising 18 703 hectares, at a capital cost of $8.7 million. Plans projected forward to 1986 targeted an additional 22 810 hectares for acquisition at an estimated cost of $11.5 million. The forecast turned out to be more optimistic than the outcome. Rather than increasing, funds to purchase land began to diminish from about 1978 onward, and in 1984, the entire land acquisition program was halted by the sharp budgetary cutback of that year.

Interestingly, the decline in the federal budget allocations for habitat acquisition coincided with a major increase in concern about habitat protection and preservation on the part of wildlife professionals and concerned voluntary organizations. The theme of the Forty-third Federal–Provincial Wildlife Conference, held in Regina, Saskatchewan, in 1979, was "Habitat is the Key."

More than 75 delegates attended that conference; of that number, close to one-third appeared on the program as speakers or panelists addressing questions of habitat. In addition to wildlife biologists and civil servants, the roster of participants included foresters and lawyers, landowners and land use planners, economists, and representatives of a variety of nongovernment organizations. The topics discussed ranged from funding and potential revenues to the ethics of land use planning and the spiritual values inherent in wildlife.

Many of the opinions were interesting and worthwhile. A few were downright prophetic. Speaking at one of the panel discussions, Stewart Morrison, then Executive Vice-President of Ducks Unlimited (Canada), confronted the question of "Who should pay?" His answer, at least with reference to waterfowl, was this: "Quite frankly, the American hunter is going to have to pay the difference between what is in the best interests of Canadian society to produce, and what is required south of the border."[21]

Alan Loughrey, Director General of CWS, summarized the same panel session, noting references to "a backlash against government buying and owning land." Contemplating alternative methods, he suggested that:

> maybe you have sort of the kernel of an escape route there, if you will, by having a sort of a trust relationship with some of the user organizations to do the spending. The other possibility is, I suppose, a wildlife habitat trust foundation in the same way that there are heritage foundations which spend tax money plus donations to acquire heritage buildings or sites for general public use."[22]

In light of the vastly expanded approach to wetland habitat conservation that was to emerge over the next 10 years, the context of these two comments merits consideration. Stewart Morrison's observation about requirements "south of the border" reflected a rising American sensitivity about significant population declines in preferred waterfowl species that had occurred during the mid-1970s. The flyway councils in the United States were demanding management plans linked to the enhancement of specific populations. At one point, proposals for as many as 35 distinct population management projects, including 15 for Canada Goose populations alone, were on the table simultaneously, each requiring its own share of financial and human resources.[23] Alan Loughrey's point regarding the need for arm's-length participation by some third party that could receive and disburse funds reflected the dilemma facing CWS: namely, that the logistics of delivering so many species-centred projects at once would be overwhelming, especially at a time when fiscal restraint was a clearly emerging theme at Treasury Board.

Furthermore, biologists involved in the CWS Habitat Program were becoming increasingly convinced that tightly focused species/population management projects would prove to be not only ruinously expensive, but also a wholly inadequate response to the need. In their view, habitat really was the key. Overhunting, disease, and other population-linked issues were largely peripheral to the broad-scale challenge of habitat loss. Intensive management of small, protected areas would never be enough to generate the quantity of waterfowl that the North American hunting fraternity desired. There must be some way to conserve and protect nesting, rearing, staging, and wintering habitat on a far grander scale.

A Continental Vision

Conversations on this theme had begun in 1977, with the blessing of both Environment Canada and the United States Department of the Interior. The CWS Program Review Committee had actually put forward a proposal for a coordinated, international waterfowl management plan, which eventually raised sufficient interest that it won the endorsement of the North American Wildlife and Natural Resource Conference that took place in Toronto in 1979. Shortly thereafter, Canada's Minister of the Environment, the Honourable Len Marchand, and the United States Secretary of the Interior committed their respective wildlife services to prepare a plan.

The preamble to this decision was the background against which two CWS directors, Michael R. (Mike) Robertson of Western and Northern Region and Hugh Boyd of the Migratory Birds Branch, put their heads together and agreed to assign two of their key people to devise a comprehensive discussion paper on what Canada would like to see in a North American waterfowl management strategy. J. H. (Jim) Patterson was in charge of the Prairie Migratory Birds Research Centre in Saskatoon. George Finney was Chief of Migratory Birds Research in Ottawa. They made a well-matched team with a flair for innovation and a strong conviction that effective wildlife management depended first and foremost on a pragmatic approach to problem-solving. As Jim Patterson put it, "Site-specific demonstration projects were all very well, but we had reached the stage where something had to happen in the working landscape where whole wildlife populations were being subjected daily, for better or worse, to the results of land use decisions."[24]

At first glance, the urgent need to protect habitat quality appeared to run directly counter to Treasury Board attempts to limit public expenditures on land. The formerly generous funding for outright acquisition of habitat was rapidly drying up. An annual budget of $1.2 million in the early 1970s had dwindled to about $400 000 a year by 1980–1981. Patterson and Finney turned the argument around. They proposed that the goal of a waterfowl management plan should not be to own limited amounts of habitat, but rather to promote responsible stewardship among private landowners and thus limit the wide-scale destruction of habitat everywhere.

The new perspective won the ears of many who heard it in both Canada and the United States. Nevertheless, the need for money was inescapable, whether for land purchase or to promote stewardship. For many years, money for conservation had been raised in the United States through the sale of an annual duck stamp. Could the same idea be imported to Canada? With the backing of the Wildlife Habitat Coalition — a broad-based alliance of some 30 wildlife and environmental agencies and organizations — a proposal went forward to Cabinet to institute a conservation stamp that would be sold to hunters along with the annual federal permit to hunt migratory birds. The submission outlined three options. Revenues from the stamp could go: (a) directly to CWS; (b) to a newly established Crown foundation; or (c) to an arm's-length foundation. The Cabinet granted approval in principle to the third option, the creation of the Wildlife Habitat Canada Foundation.

One major obstacle stood in the way. The Financial Administration Act of Canada states that all public money shall be paid into the consolidated revenue fund, and Treasury Board has developed detailed regulations governing the handling of this money. In defence of this principle, representatives of the Treasury Board argued strenuously that any revenues generated by the sale of a special stamp would fall under these regulations and thus could not be earmarked for the specific purpose of conservation. The debate grew heated at times, as Jim Patterson later recalled:

> At one unforgettable meeting, the Treasury Board analyst who wrote the rules and who had been fighting us tooth and nail looked me square in the eye and said, "You are proposing to violate the public accounts of Canada." If he had accused me of proposing gross indecency he couldn't have sounded more outraged.
>
> Eventually the whole matter got bumped up to the level of Assistant Deputy Ministers for a decision. George Finney and I presented the case for Wildlife Habitat Canada. Treasury Board did their best to rebut our arguments. Fortunately, George had really done his homework. A close study of the Treasury Board rules, and a lot of consultation with allies in the Privy Council Office and elsewhere, had convinced him that the solution we were proposing really was permissible.
>
> At the crucial meeting, he gave a short, eloquent speech, straight from the heart. At the last moment, as it was becoming clear that he was winning the support of the group, the Treasury Board representative pounded the table and shouted, "I wrote the rules, dammit! I should know what's in them."
>
> George replied very evenly, very quietly, "Yes. But we're right."
>
> That won the day.[25]

More than a century of agricultural conversion has left the prairies with very little native grassland habitat. In recent years, habitat managers such as Phil Taylor have initiated important prairie restoration projects. Grassland ecologist Dean Nernberg is seen here processing native grass seed at Last Mountain Lake National Wildlife Area in 1994 (Photo credit: P. Taylor).

Wildlife Habitat Canada was officially established in 1984 with a mandate to conserve, restore, and enhance wildlife habitat. It was governed by a board that included three representatives of the federal government and three from the provinces and territories, as well as nominees from selected nongovernment organizations.

David J. Neave, formerly head of the Province of Alberta's wildlife habitat program, was appointed as Executive Director. Under his leadership, Wildlife Habitat Canada has actively promoted stewardship as the core value of a landscape approach to conservation, working with governments, voluntary organizations, and resource-based industries to develop programs that will conserve soil, water, and wildlife in agricultural, forested, coastal, northern, and urban settings. In addition to contributing millions of dollars to land acquisition, it has funded habitat research, scholarships, and educational projects. It has been a participant in a wide range of practical pilot projects and has encouraged thousands of landowners in adopting sound land use practices. Wildlife Habitat Canada has provided CWS with an arm's-length partner in promoting conservation ventures and a valuable ally in forwarding the development and adoption of the continental waterfowl management strategy.

Meanwhile, progress towards the elaboration of a Canadian position on a North American waterfowl strategy was slow. Because responsibility for waterfowl management is shared between the federal and the provincial and territorial governments in Canada, the process was so fraught with constitutional ambiguities that it was fundamentally the status of the Migratory Birds Convention as a so-called "Empire Treaty" that assured CWS of standing in the negotiations. There were other potential pitfalls as well. By the mid-1980s, the National Energy Plan had become a sore point with some western provinces. Waterfowl management provided them with an ideal collateral issue on which to press for the acknowledgment of outright provincial control of natural resources. Another stumbling block that had to be addressed was the question of how to allocate a fair share of the annual harvest to hunters living in the breeding and wintering ranges of the birds.

It is a testimonial to the sense of common purpose shared by Canada's wildlife directors and their allies and associates that, despite such challenges, Patterson and Finney were able to produce a position paper that was acceptable all across Canada in less than seven years. What seemed more remarkable at the time, although in retrospect it was surely a benefit of the painstaking negotiations within Canada, was the fact that it took only seven months to arrive at a mutual agreement on the plan with the Americans.

The process was aided by a growing awareness, worldwide, of the importance of ecosystem conservation. It embodied a vision of environmental responsibility that was right for the time. Although the North American Waterfowl Management Plan (NAWMP) was signed in 1986, a full year before the report of the Brundtland Commission was tabled at the United Nations, it already exemplified the concept of sustainable development of landscapes. Land use practices that would serve to enhance waterfowl populations were, by definition, practices that would also help to conserve soil and water for farming and forestry. In addition, the statistical work that CWS socioeconomist Fern L. Filion was doing on the economic value of wildlife provided yet another demonstration of the benefits that would accrue to communities, regions, and countries that would commit to wetland habitat protection on a broad scale.[26]

Getting NAWMP signed was one thing. Getting it implemented was quite another and took the assistance of a wide range of allies. Ducks Unlimited (Canada) had been a participant in the Canadian discussions leading up to the plan since 1982–1983, and although its American parent organization tended to oppose the concept, Stewart Morrison, then Executive Director of the Canadian organization, became a convert and undertook to sell his American counterparts on the concept. Gary Myers, Director of Wildlife for the State of Tennessee, was serving as President of the International Association of Fish and Wildlife Agencies in 1986. A firm believer in NAWMP, he struck a committee to implement the plan. Three years later, Jim Patterson became president of the International Association of Fish and Wildlife Agencies and from that vantage point gained a level of access in Washington that was unprecedented for any Canadian wildlife official. So successful was he at lobbying for the waterfowl management plan that, in a comment that echoed the outrage that had been expressed by a Canadian Treasury Board analyst some six years earlier, he was accused of "exercising undue influence on the jurisprudence of the United States of America."[27]

What was needed were some demonstration projects to show that the concept of a coordinated habitat protection plan could work on the ground. Although the plan called for a 75:25 split between American and Canadian funding, Patterson proposed a 50:50 ratio for the first venture. On that basis, the Director of Wildlife for the State of New York volunteered to commit $100 000 to a first-step project. Ducks Unlimited agreed to match that amount, and the National Fish and Wildlife Federation chipped in with another $200 000. At this point, Patterson began to feel some trepidation as to how he would secure matching funds (about $500 000 in Canadian dollars, given the current rate of exchange) from north of the border. In fact, once the initial pledges had been made, many more American funding sources wanted to be part of the new undertaking. By the time Patterson reported to the Honourable Tom Macmillan, Canada's Minister of Environment, the ante had reached $5 million. To his great relief, Macmillan approved the commitment in principle.

Even then, success was not assured. Locations for the proposed activity were strategically located across Alberta, Saskatchewan, and Ontario, with a

Key players from a variety of conservation organizations gathered, in 1985, to witness the signing of an agreement under which core funding for Wildlife Habitat Canada (WHC) would be acquired through annual sale of a conservation stamp. Signing the document are Stewart Morrison of Ducks Unlimited (Canada), then Chair of WHC, and the Honourable Tom Macmillan, then Minister of Environment. Onlookers (*l. to r.*) included: Susan Prebinski (WHC), Dave Neave (WHC), Colleen Hyslop (CWS), Steve Curtis (CWS), Jim Patterson (CWS), Elizabeth May (Minister's Office), Ken Cox (WHC), Lynda Maltby (CWS), Jim Vollmershausen (Parks Canada), Tony Clarke (Director General, CWS), and George Finney (CWS) (Photo credit: CWS).

keen view to the importance of two factors — waterfowl habitat and public awareness. The provinces would contribute one-third of the Canadian share, another share would be provided by nongovernment sponsors, and the last third would come from the Government of Canada. To secure the federal share, Patterson arranged a meeting with New Brunswick industrialist Arthur Irving, a committed conservationist and outdoorsman who was, at the time, president of Ducks Unlimited (Canada), a few other prominent supporters from the private sector, and the federal ministers of Environment, Agriculture, and Western Economic Development. Officials in some of the sponsoring departments resisted the arbitrary transfer of funds to projects beyond their control. Nevertheless, the ministers were convinced, largely by the demonstrable potential for sustainable economic benefits, and the project went ahead.[28]

Once a few pilot projects had been put together, the support of governments in both the United States and Canada began to grow. In Washington, the Congress passed the North American Wetlands Conservation Act. Money began to flow from government and nongovernment sources. Almost more important, however, was the degree to which wildlife managers across North America began to shift their attention away from species and towards habitat, away from narrowly defined protected areas and towards broad strategies of stewardship. A North American Wetlands Conservation Council was formed as the governing body for NAWMP. A Canadian wing of the Council, consisting of representatives from CWS, Wildlife Habitat Canada, Ducks Unlimited (Canada), the Nature Conservancy of Canada, and provincial delegates from each of the Canadian Joint Ventures, oversees activities in Canada.

Not only government agencies but also landowners and corporations have become involved in NAWMP partnerships. Many jurisdictions have passed legislation enabling the establishment of covenants to guarantee that specified conservation values will be respected on designated lands. In Canada, changes introduced to the Income Tax Act in 1995 made it possible for people who donate gifts of land for conservation purposes to qualify for tax relief. Under this revision, the Minister of the Environment was given responsibility for identifying ecologically sensitive land and certifying ecological gifts. The job of implementing this initiative fell to CWS, and specifically to Clayton (Clay) Rubec of the Habitat Conservation Division. In the first three years since the inception of the program, more than 50 gifts in eight provinces, with a cumulative value of over $12 million, were certified.

In its first full decade of operation as an international venture, NAWMP has made strides that, without invalidating or detracting from earlier habitat protection schemes in Canada, certainly dwarf them in scale and scope. Over 600 000 hectares of wetland and other habitat have been secured and enhanced to date under regional Joint Venture initiatives in British Columbia, the Prairies, and Eastern Canada at a cost of $347 million. The NAWMP goal calls for securement of an additional 1.5 million hectares in Canada and an additional expenditure of more than $2 billion.[29] One species-centred Joint Venture has invested more than $6 million in research on Arctic-nesting populations of Brant, Canada Goose, Ross' Goose, Snow Goose, and White-fronted Goose. Another has dedicated a similar amount to Black Duck research, and a proposal for a comparable initiative on seaducks has been approved by CWS for submission to the North American Wetlands Conservation Council (Canada).

Not only waterfowl have benefited from NAWMP. Habitat biologist Phil Taylor, always taking a holistic approach, obtained Wildlife Service NAWMP funds to study how hay management at Last Mountain Lake could accommodate the needs of shorebirds and songbirds, as well as ducks. Regional Director Gerry McKeating then expanded this ground-breaking initiative, so that many NAWMP proposals have undergone an evaluation of their effects on nongame species and been modified if there were problems.

Literally hundreds of agencies and thousands of landowners are partners in NAWMP. The plan accounts for the spending of about $30 million to $35 million on projects in Canada every year. By 1996, total contributions to Canadian projects amounted to nearly $320 million, of which $148 million came from partners in the United States, $74 million from Canadian provinces, $55 million from the federal government of Canada, and $42 million from Canadian private sources. Has there been a good return on the investment? To cite one measurable indicator of success, the number of migrating waterfowl has increased markedly since the inception of NAWMP. Aided by the plan, in conjunction with favourable climatic conditions, the 1985 estimate of 55 million birds had increased to approximately 90 million birds by 1996.[30] The overall benefits to biodiversity and wildlife in general during that period have not been quantified.

Emerging Issues

From the mid-1980s onward, fiscal and organizational changes in government influenced CWS habitat programs and activities in a variety of ways. The Lands Directorate of Environment Canada was dismantled in 1988, and the reassignment of its staff brought new expertise to CWS in the field of land use planning and strategy. Such skills were needed. The accumulation of Migratory Bird Sanctuaries, National Wildlife Areas, Western Hemisphere Shorebird Reserves, Ramsar sites (see Chapter 10), NAWMP stewardship agreements, and a host of other designations and initiatives aimed at habitat conservation had left the Wildlife Service in need of a framework to coordinate its involvement in land management.

A CWS task force, made up of habitat specialists from each of the five regions and headquarters, was assembled under the leadership of Gerry Lee, Chief of Habitat Conservation. Its purpose was to develop and articulate a coherent habitat conservation strategy for the 1990s. The group convened at Cap Tourmente in early September 1989 and worked 10 days, nonstop, to produce a draft document that was quickly endorsed by CWS management and put into practice. It left no doubt that protection of wildlife was dependent on protection and wise stewardship of habitats, landscapes, and ecosystems. The preservation of biodiversity, not just the conservation of a handful of preferred species, was the goal, and responsibility for its attainment was acknowledged to belong to all levels of government and to nongovernment organizations as well. It outlined the overall purpose of the CWS habitat conservation program in these terms: "Canada's wildlife habitat should be maintained or enhanced to sustain all species indigenous to Canada."[31] In 1992, the strategy was presented, with some revisions, to the Federal–Provincial/Territorial Ministers' Conference on Protected Areas, and it has guided CWS habitat work since that time.

In response to a Green Plan commitment to produce a federal wetlands conservation policy, the Habitat Conservation Division was also charged with the task of drafting such a document and leading consultations on it. Clay Rubec guided the process through two rounds of consultations, leading to the adoption and announcement of a Federal Policy on Wetland Conservation. To assist federal departments and agencies in implementing the policy, the division produced a guide and subsequently participated in several meetings with the affected groups to promote a common understanding. This, the first such policy in Canada, led to the

Last Mountain Lake National Wildlife Area, established in 1887 and today the oldest wildlife preserve in Canada, was the site of a meeting of western CWS habitat staff in 1994. Present were: (*front row, l. to r.*) Sam Barry, Phil Taylor, Cathy Roger, Rolly Wickstrom, Peter Farrington, Hal Reynolds, Henk Kiliaan, Pat Rakowski; (*back row*) Tim Coleman, Len Shandruk, Stan Woynarski, John Dunlop, Jim Rogers, Garry Trottier, Paul Gregoire (Photo credit: CWS).

establishment of similar ones in several provinces and has served as a model for several other nations around the world.[32]

In recent years, the ecosystem approach to wildlife habitat management has become increasingly evident in broader, regional initiatives, usually in partnership with other agencies and organizations. In British Columbia, for example, these included not only the Pacific Coast Joint Venture under NAWMP, but also the Greenfields Project in the Fraser Delta, the Pacific Coast Estuary Program, and the Lower Fraser River Action Plan.

The Prairie Conservation Action Plan brought together a broad alliance of partners[33] to sponsor, among other things, the development of a landowner's guide to the conservation of prairie grasslands. The native grassland ecoregions having been almost entirely converted to human use, there are more endangered species and habitats concentrated in the surviving remnants than anywhere else in Canada. The 92-page book, written by Garry Trottier of CWS, provides a convenient and informative guide to Canadian grassland ecosystems, a call to stewardship action, and valuable how-to information on assessing and restoring native prairie habitat.[34]

The Action Plan model, involving large numbers of stakeholders, from federal and provincial government departments to individual landowners, has been applied, with appropriate regional variations, across much of Canada. In Ontario, the Great Lakes Action Plan grew out of a desire to rehabilitate aquatic, wetland, and shoreline habitats in the wake of the toxic contaminant problems of the 1970s and 1980s (see Chapter 8). Activities within the framework of the plan range from enhancement projects dedicated to particular species, such as Osprey and Caspian Tern, to shoreline restoration and "best practices" programs in agriculture, forestry, and fish and wildlife management.[35]

In the Quebec Region, the past 25 years have seen the role of CWS evolve from specific surveys and studies towards a greater diversity of environmental projects and interests. The St. Lawrence Action Plan has become the flagship habitat program in that region. It has been a major source of funding for a wide variety of wildlife conservation initiatives, facilitating the protection of more than 12 000 hectares by a range of partners that included not only CWS but the Government of Quebec and non-government participants.

Where habitat biologists like Denis Lehoux and Luc Bélanger might formerly have concentrated on specific surveys and studies, their work now includes a greater diversity of projects, such as watershed assessments or the development of technology for restoring eroded streambanks and diked marshes. The St. Lawrence Action Plan has supported the work of Jean Rodrigue and Louise Champoux in researching herons, gulls, Snapping Turtles, and Mudpuppies as bioindicators of habitat health in the river. It has likewise enabled Michel Robert, Pierre Laporte, and François Shaffer to develop action plans for the protection and restoration of the Yellow Rail in St. Lawrence wetlands[36] and of the Piping Plover and Horned Grebe in the Magdalen Islands.

In addition to participating in regional environmental action plans, CWS renewed its interest in the establishment of National Wildlife Areas. A new set of criteria was developed to guide the selection of sites, including the presence of significant populations of migratory birds, rare and endangered species, and unique fauna, flora, or habitat. Steps were taken to advance the declaration of new National Wildlife Areas in the Northwest Territories, Yukon, and Alberta. An area comprising more than 10 500 hectares of waterfowl and shorebird habitat was designated at Last Mountain Lake where, in 1887, Canada's first protected wildlife area had been set aside. By 1995, CWS was directly responsible for protecting more than 115 000 square kilometres of territory — 46 National Wildlife Areas under the Canada Wildlife Act and 98 Migratory Bird Sanctuaries under the Migratory Birds Convention Act. In addition, an innovative amendment to the Canada Wildlife Act in 1994 broadened the definition of wildlife to include all wild organisms, both plant and animal. The same amendment also extended protection to "the habitat of any such animal, plant, or other organism" and allowed for the creation of marine National Wildlife Areas in waters up to 200 nautical miles (370 kilometres) offshore. Habitat protection commitments announced in 1995 included development of an overall CWS marine habitat conservation strategy and regional marine bird conservation strategies for Canada's Pacific and Atlantic coasts.[37]

Increasingly, cooperation and partnership have become the preferred habitat conservation strategies of government, institutional, corporate, and voluntary sectors in the 1990s. This trend has encouraged CWS to become a participant in many initiatives that would have fallen far outside the parameters of its mandate in the early years. Thus, Habitat Conservation Chief Gerry Lee found himself representing Environment Canada on the National Roundtable on Sustainable Forests. It was an opportunity to make a strong case for wildlife and habitat conservation to a variety of stakeholders, including the forest industries, for whom it had not traditionally been a priority.

Another, still more striking instance of CWS involvement in a nontraditional area also arose through a forestry connection. Following the adoption of the Convention on Biological Diversity, the government of Mexico invited a team of specialists from the Canadian Forest Service, as well as delegates from two Canadian Model Forests and from the CWS Habitat Conservation Division, to advise on how to manage the mountain forests that are the wintering grounds of the Monarch Butterfly in such a way as to protect the critical habitat of the migratory insect. CWS subsequently proposed the creation of Monarch Butterfly reserves in both Mexico and Canada. An accord was reached in 1995, and that year three sites in southern Ontario — Point Pelee National Park, Long Point National Wildlife Area, and Prince Edward National Wildlife Area —were the first to be so designated.

Notes

1. Canada, Department of Resources and Development, *Annual Report* (Ottawa, 1953), page 32.
2. Wendy Simpson-Lewis, Jennifer E. Moore, Nancy J. Pocock, M. C. Taylor, and Hedley Swan, *Canada's Special Resource Lands: A National Perspective of Selected Land Uses* (Ottawa: Environment Canada, Lands Directorate, 1979), page 132.
3. A. D. Smith, personal communication, interviewed at Sackville, New Brunswick, 23 October 1997.
4. Herman J. Dirschl, "Recreational use of Last Mountain Lake Migratory Bird Sanctuary" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967), page 20.
5. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975).
6. Herman J. Dirschl, "Land capability for wildlife production of the western Saskatchewan River Delta" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 19 67), page 14.
7. cf. H. J. Dirschl, *Evaluation of Ecological Effects of Recent Low Water Levels in the Peace–Athabasca Delta* (Ottawa: Canadian Wildlife Service Occasional Paper Number 13, 1972); and H. J. Dirschl, D. L. Dabbs, and G. C. Gentle, *Landscape Classification and Plant Successional Trends in the Peace–Athabasca Delta* (Ottawa: Canadian Wildlife Service Report Series, Number 30, 1974).
8. William R. Miller, "Delta Marsh Management Plan" in Canada, Department of Indian Affairs and Northern Development, *Canadian Wildlife Service '66* (Ottawa: Queen's Printer, 1967), page 23.
9. J. B. Millar, *Wetland Classification in Western Canada: A Guide to the Marshes and Shallow Open Water Wetlands in the Grasslands and Parklands of the Prairie Provinces* (Ottawa: Canadian Wildlife Service Report Series, Number 37, 1976).
10. Lewis, *Lively*, page 374. (See note 5)

11. V. Solman, personal communication, telephone interview, 12 March 1998.
12. CWS Task Force, *Environmental Assessment in CWS* (Ottawa: Canadian Wildlife Service, 1990).
13. The Honourable Arthur Laing, *Canada's National Wildlife Policy and Program*, a statement made by the Minister of Northern Affairs and National Resources in the House of Commons on 6 April 1966 (reprint).
14. Canada, Department of Indian Affairs and Northern Development, *Annual Report: 1968–1969* (Ottawa, 1970), pages 16–17.
15. Lewis, *Lively*, page 454. (See note 5)
16. Smith, personal communication. (See note 3)
17. W. E. Godfrey, *The Birds of Canada*, revised edition (Ottawa: National Museum of Natural Sciences, 1986).
18. L. Shandruk, personal communication, interviewed at Edmonton, 2 December 1996.
19. Brenda Dale, personal communication, letter to P. Logan dated 28 August 1998.
20. W. R. Whitman, *Impoundments for Waterfowl* (Ottawa: Canadian Wildlife Service Occasional Paper Number 22, 1976).
21. D. S. Morrison, Remarks in *Transactions of the 43rd Federal–Provincial Wildlife Conference* (Ottawa: Canadian Wildlife Service, 1979), page 165.
22. A. G. Loughrey, Remarks in *Transactions of the 43rd Federal–Provincial Wildlife Conference* (Ottawa: Canadian Wildlife Service, 1979), page 179.
23. George Finney, personal communication, interviewed at Sackville, New Brunswick, 24 October 1997.
24. J. H. Patterson, personal communication, interviewed at Ottawa, 1 November 1997.
25. Patterson, personal communication. (See note 24)
26. cf. F. L. Filion and S. A. D. Parker, *Human Dimensions of Migratory Game-Bird Hunting in Canada* (Ottawa: Canadian Wildlife Service Occasional Paper Number 52, 1984); and F. L. Filion, S. W. James, J.-L. Ducharme, W. Pepper, R. Reid, P. Boxall, and D. Teillet, *The Importance of Wildlife to Canadians: Highlights of the 1981 Survey* (Ottawa: Canadian Wildlife Service, 1983).
27. Patterson, personal communication. (See note 24)
28. Patterson, personal communication. (See note 24)
29. North American Wetlands Conservation Council, *Agenda for the NAWCC (Canada) Meeting, 7–8 July 1997,* Annex 1a (1997).
30. North American Waterfowl Management Program Communications, *Taking Flight 1986–1996: 10th Anniversary Report — Canada* (Hull, Quebec: North American Waterfowl Management Plan, 1997).
31. Environment Canada, *An Action Plan for Wildlife Habitat* (Hull, Quebec: Canadian Wildlife Service, 1992).
32. Government of Canada, *The Federal Policy on Wetland Conservation* (Ottawa, Environment Canada, Canadian Wildlife Service, 1991).
33. Partners in this venture include CWS, Environment Canada, the World Wildlife Fund, Prairie for Tomorrow, the North American Waterfowl Management Plan, Prairie CARE Partners, and Ducks Unlimited (Canada).
34. Garry C. Trottier, *A Landowner's Guide: Conservation of Canadian Prairie Grasslands* (Edmonton: Environment Canada, Canadian Wildlife Service, 1992).
35. Environment Canada, *Rehabilitating Great Lakes Habitats: A Resource Manual* (Downsview, Ontario: Environment Canada, Environmental Conservation Branch, Conservation Strategies Division, 1996).
36. Denis Lehoux, personal communication, interviewed at Quebec City, February 1997.
37. Water and Habitat Conservation Branch, *Conserving Wildlife Habitats* (Ottawa: Environment Canada, Canadian Wildlife Service, 1995).

1972–1977: Regionalization

In his remarks to the 37th Federal–Provincial Wildlife Conference, held in Ottawa in July 1973, Director General John Tener noted that CWS had marked its 25th anniversary the previous November.[1] From its modest beginnings, with a professional staff of nine and an annual budget of $175 000, the agency had risen to a strength of about 370 people and a budget of $10.7 million. In view of such growth, it was scarcely surprising that national staff meetings had been abandoned as impractical about a decade earlier.

What might be considered somewhat more unusual was the fact that the structure of the agency had changed very little in its 25 years of operation. Apart from the creation of two regions to administer field operations, the original concept of an integrated, national wildlife management team was essentially intact. It would not remain so for much longer.

Effective 1 January 1973, the Federal Cabinet gave final approval to the reorganized Department of the Environment. Regionalization was very much the fashion among government planners of the day, and the administrative model adopted for the newly amalgamated Environment Canada was in the vanguard of fashion.[2] A system of management was introduced within the larger department that would group the various components of the department — fisheries, forestry, wildlife, lands, waters, atmosphere, etc. — under a Regional Director General within each of five regions. In fact, another two years passed before CWS took steps to implement this model, but how to accomplish the transformation was a major preoccupation of senior management from 1972 onward.

A further complicating factor for the CWS leadership was the slow progress of the Canada Wildlife Act through the successive processes of discussion, negotiation, and legislation. As early as 1966, the Cabinet had announced its intention to bring in such a bill, but a change of prime minister, four ministers, two general elections, and the complete reshuffling of the environmental portfolio had intervened since then. It was not until July 1973 that the Act became law.

Meanwhile, for CWS people in the field, business continued as usual. The range of activities that they were engaged in provided a good measure of the extent to which the Wildlife Service had grown since its inception. The issuing of migratory bird hunting permits and the conduct of the associated surveys were undergoing a major redesign. The motivation and the ability to embark on such a task reflected the fact that computer-based information processing was now available to a growing number of organizations, including CWS. The Breeding Bird Survey and the Canadian Nest Record Scheme were other beneficiaries of this new technology, as were a host of other functions that depended on statistical analysis. Biometric studies and economic investigations of nonconsumptive uses of wildlife became more practical as the ability to manipulate data improved.

Habitat protection and land acquisition for National Wildlife Areas continued apace. In the Vancouver area, the addition of the 270-hectare Reifel Farm and Refuge to federally owned foreshore lands on Westham Island enabled the establishment of a major conservation site within a short drive of the city centre. In central British Columbia, land assembly was under way for the Vaseaux Lake National Wildlife Area, while in eastern Canada, nine National Wildlife Areas were now in place, with another nine in the process of being purchased and still more candidate sites at various stages of evaluation. Interpretive centres were now open at Wye Marsh in Ontario and at Percé and Cap Tourmente in Quebec. A fourth centre, at Creston, British Columbia, was under construction (see Chapter 7).

Migratory game bird monitoring continued to be an important preoccupation across the country. Construction of a 930-square-metre expansion at the Prairie Migratory Bird Research Centre in Saskatoon underlined the continuing importance of that region as North America's "duck factory." Another new construction project, the Raptor Breeding Centre at Wainwright, Alberta, indicated that the scope of ornithological work was expanding well beyond the original concentration on migratory game birds. In eastern Canada, concern was mounting over the need to investigate declines in the Black Duck population. Seabird and shorebird research programs were also gaining momentum on all coasts and on the Great Lakes as well, and seabirds were attracting attention for their potential as indicators of marine environmental quality.

Work with Caribou, Wolves, Polar Bears, Bison, and other species continued to sustain the reputation of CWS as an important institution for mammal research. It also kept the veterinarians of the Pathology Section busy carrying out anthrax vaccinations and testing for tuberculosis and brucellosis, examining parasites in bird and animal samples from across the country, and responding to a recent concern that outbreaks of duck virus enteritis in the United States might spread to Canada.

Heightened public concern about the state of the environment had led to the introduction of formal environmental impact assessment protocols as a preliminary to government approval of a wide variety of economic development projects involving either resource extraction or the building of infrastructure. As the federal authority on wildlife management, CWS found itself involved in an increasing number of impact studies and reviews and contributed to the development of guidelines for future environmental impact assessments.

The mid-1970s were a period of transition for CWS, not only in its organization, but in the ways it did things and the variety of things it did. As John Tener expressed it:

> The most vital advances in the service last year are in methodology rather than accomplishment. We are acting on an ever-larger stage, we are doing things more directly for other people, we are doing things with other people rather than alone. As a result, we are exchanging more information.
>
> ...The new department has had a great deal to do with this, through the emphasis that has been placed on developing mechanisms to focus expertise from all federal agencies with environmental interests onto federal, provincial, corporate, and private activities across the country, from offshore drilling in the Atlantic to the industrial use of estuarine land on the Pacific; from pollution control in the Great Lakes to environmental assessment of pipeline routes in the western Arctic.[3]

The following year, the pace of change accelerated. The new department created new opportunities, and Tener himself was promoted to Assistant Deputy Minister of Environment Canada. He was succeeded at the helm of CWS by Alan Loughrey. The Wildlife Service retained its two-region structure through 1974 and into 1975, but Loughrey announced that conversion to five regions, in conformity with the rest of Environment Canada, would be only a matter of time.[4]

Even so, the transition was a slow one. A year later, the two regions were still in place, although Andrew Macpherson had accepted a promotion to Regional Director General, Western and Northern Region, Environment Canada, where he described the task of coordinating the interests of half a dozen competing and independent-minded agencies as being "something akin to trying to herd cats."[5] Doug Stephen followed him as Director, CWS, for the Western and Northern Region.

Women began to make their presence felt in the technical and professional ranks of many organizations in the 1970s. When Barbara Campbell (*l.*) and Lynne Allen joined Lynda Maltby to band Snow Geese in 1975, the trio was the first all-female research party in the history of CWS (Photo credit: L. Maltby).

At headquarters in Ottawa, the advance of reorganization was becoming more evident. A new structure was introduced in the spring of 1975 that saw the work of the head office divided into branches. The Migratory Birds Branch, headed by Hugh Boyd, became responsible for migratory bird surveys, regulations, enforcement, crop damage control, environmental assessment work, and habitat acquisition and management. The Wildlife Management Branch, under Tony Keith, encompassed cooperative research projects, toxic chemicals, interpretation, pathology, and bioelectronics. The Advice and Support Branch, directed by Jean-Paul Cuerrier, was concerned with limnology, biometrics, social research, and information. D. K. (Doug) Pollock continued to manage CWS Administration. It was not until late in 1975 that the final stage of reorganization came into effect with the creation of five geographically based regions whose internal structure more or less paralleled that of headquarters with its four national branches.

Reorganization posed a number of challenges for the Wildlife Service. The region-centred "matrix management" system of Environment Canada was felt by some to diminish the agency's national focus on wildlife in favour of more general environmental concerns on a regional scale. Another challenge had to do with one of the unwritten laws of organizational ecology: namely, that reorganization often tends to increase the population of managers and diminish the population of workers. Each of the five new regions required its own Director: James Inder (Atlantic), Pierre Desmeules (Quebec), Joe Bryant (Ontario), Mike Robertson (Western and Northern), and Gordon Staines (Pacific and Yukon). Answering to each Director were four Chiefs. The total of 25 managerial positions in the field was about three times what had been needed previously.

Although it created opportunities for promotion throughout the system, the demand for additional managers was perceived as a negative influence by those who saw it as taking senior biologists away from scientific work at a time when their expertise was of vital importance. Be that as it may, by 1977, the five-region model was fully entrenched at CWS and remained so, without major adjustment, for the next decade.

On the other hand, the closer association with allied agencies within the Environment Canada matrix did afford unprecedented opportunities for cooperation. A case in point arose in the Ontario Region, where the Regional Director General of the Environmental Management Service, "Bud" Smithers, responded positively to a CWS proposal that would involve all the elements of the new organization. Steve Curtis and Guy Morrison, CWS biologists in the region, conceived the idea of developing a baseline study of the Hudson Bay Lowlands, an important migration and breeding area for shorebirds.

Curtis had recent experience in the development of the James Bay and Northern Quebec

Agreement, and Morrison had been conducting shorebird research on the Ontario coast of James Bay. There were environmental threats on the northern Ontario horizon, involving possible hydroelectric developments, mining, and peat extraction. Curtis and Morrison argued that the time to assess the ecology of an area such as the Hudson Bay Lowlands was before any of those threats became a reality. Joe Bryant, then CWS Regional Director for Ontario, had advocated similar baseline studies in the eastern Arctic for years without success. He was delighted to be able to nourish the Curtis–Morrison plan and found a keen supporter in Smithers.

Under the matrix management scheme, Smithers had control of the budgets of all the components of the Environmental Management Service and, after discussion with his several regional directors, ordered budgets and manpower from CWS, Inland Waters, the Canadian Forestry Service, and the Lands Directorate to be assigned to the project. The project, which also involved the National Water Research Institute and the University of Guelph, went well and resulted in new knowledge of a very complex and ecologically fragile area of Canada. Without the matrix management system and the backing of a progressive Regional Director General, it might never have been undertaken.

Notes

1. J. S. Tener, "Report of the Canadian Wildlife Service" in *Transactions of the 37th Federal–Provincial Wildlife Conference*, 9–12 July 1973, Ottawa (Ottawa: Canadian Wildlife Service, 1973), page 18.
2. Many federal departments and agencies embraced some degree of regionalization or decentralization during the mid-1970s in response to growing demands that the centre of Canada should acknowledge legitimate variations in identity in outlying parts of the country. The National Film Board, for example, established production centres in Halifax, Toronto, Winnipeg, Edmonton, and Vancouver to provide opportunities for young film makers across the country. The Canadian Broadcasting Corporation increased its commitment to regional programming on both radio and television.
3. Tener, "Report of the Canadian Wildlife Service," page 17. (See note 1)
4. Alan Loughrey, "Report of the Canadian Wildlife Service" in *Transactions of the 38th Federal–Provincial Wildlife Conference*, 25–27 June 1974, Victoria (Ottawa: Canadian Wildlife Service, 1974), page 12.
5. Andrew Macpherson, personal communication, 3 December 1996.

CHAPTER 7: Telling the Wildlife Story

From the outset, it was evident to Harrison Lewis that any hope for success in conserving Canada's wildlife would depend to a large degree on success in fostering public awareness and understanding. As head of the new agency, he travelled extensively across Canada and into the United States, a tireless evangelist for conservation wherever he went. One cannot read his own record of the period from 1947 to 1952 without being struck by the number and variety of meetings, speaking engagements, and media interviews that he undertook. By directive and example, he encouraged the staff of the Wildlife Service to do likewise. A few excerpts from his notes concerning a trip to San Francisco in 1950 to attend the Fifteenth North American Wildlife Conference illustrate the point:

> ...[I] decided that I should make a series of useful calls at points in western Canada while on my way....On February 20 I arrived at Winnipeg, where I spent two days in interviews with the provincial Minister of Mines and Natural Resources, members of his staff, Dominion Wildlife Officer D. G. Colls, officers of the RCMP, officials of the Hudson's Bay Company, members of the faculty of the University of Manitoba, and local naturalists. February 22, I spent in Regina, where I attended the annual meeting of the Saskatchewan Fish and Game League and took part in another round of interviews. On February 23, in Saskatoon, I addressed a seminar at the University of Saskatchewan concerning the Wildlife Division, its organization and functions, and had yet another series of interviews. Arriving in Edmonton in the late morning of February 24, I interviewed Dominion Wildlife Officer J. Dewey Soper, provincial officials, officers of the RCMP, members of the university faculty, and others. In Calgary, on February 25, I had additional interviews....
>
> I arrived in Banff at noon on February 26...and on the 27th I lectured to the Alberta Extension Short Course on Wildlife Management on the subject, "Purposes and Aims of Wildlife Management."
>
> ...On March 2 at Vancouver there were many more interviews. In addition I addressed a group of advanced wildlife students of the University of British Columbia concerning the Wildlife Division and its work. Most of March 3 I spent at Victoria, where there were more interviews....
>
> I travelled south from Seattle by train and arrived at San Francisco late in the morning of March 4. On March 5 I attended a meeting of the Pacific Flyway Waterfowl Committee and a meeting of the Natural Resources Council of America, and took part in numerous interviews. During the three-day period, March 6–8, D. A. Munro and I represented the Wildlife Division [at the Wildlife Conference]. I presented...a paper entitled

"Aspects of Conservation Education in Canada." Mr. Munro presented a paper entitled "Review of Waterfowl Conditions in Canada." Each day I was a participant in many interviews.[1]

The return trip, which included visits to wildlife refuges in Utah, was scarcely over when he was addressing the Smiths Falls Hunt Club "on the subject of the Wildlife Division and its work."

Talks to wildlife conferences, naturalists' clubs, law enforcement agencies, and fish and game associations played an important role in establishing the Wildlife Service as a presence among conservation organizations. Still, such activities, though of immense importance, consisted largely of preaching to the converted. That Lewis himself was sensitive to this limitation is clear in his observation that "public relations services in connection with organized wildlife management are very inadequate."[2] Vic Solman, in an address to the International Association of Game, Fish, and Conservation Commissioners in Dallas, Texas, on 12 September 1952, bluntly outlined the scale of the challenge when he said:

> I believe that the majority of the people, who do not now appreciate wildlife and who consequently are unwitting assistants to its depletion, are unfortunate in that they do not have clear statements of the uses and values of wildlife constantly placed before them. They contribute to the steady destruction of renewable resources, not through malice, but through ignorance of any other method of use. Our greatest need, then, is to reach these people and to put before them now, often, and continually, the facts which will enable them to understand and appreciate wildlife and to help them to become willing workers in its defense.[3]

CWS was already publishing scientific information in its *Wildlife Management Bulletins* series, and, indeed, the publication of research results has remained a priority to the present day. Despite numerous budget cuts and reorganizations, the Wildlife Service has continued to maintain a small publishing and information unit at headquarters. Dedicated editors such as Darrell Eagles, John Cameron, Eleanor Kulin, and Pat Logan designed effective vehicles for disseminating wildlife research and ensured that peer review of papers was as rigorous as that for scientific journals. In 1957, the *Wildlife Management Bulletins* were replaced by a series of *Occasional Papers*,[4] and in 1966, the first of the Wildlife Service's *Reports*[5] appeared. While the former were written to communicate results of specific projects to other scientists, the latter used colour photographs and lay language to reach a broader audience. *Progress Notes*,[6] interim reports to wildlife managers on ongoing research, were also launched in 1966 and became an important medium for publishing data on hunting activity from the annual National Harvest Survey and on migratory bird populations from the Breeding Bird Survey. In 1986, the regionalization of CWS was reflected in the introduction of the *Technical Reports* series to encourage each regional office to publish results of local interest.

An analysis of citation records in 1994 showed that *Occasional Papers* and *Reports* compared well in frequency of use with general zoological journals such as the *Canadian Journal of Zoology* and the *Journal of Wildlife Management* and continued to be cited for many years after publication. As well as embodying the professionalism of CWS research, the scientific publications have helped to maintain the identity of the Wildlife Service as a national organization in the 1990s, when regional integration of Environment Canada activities might otherwise have submerged its well-known name.

Nonetheless, such writings have, of necessity, been aimed at a scientific readership. As Vic Solman observed to his listeners in Dallas in 1952:

> Most of the research scientists have neither the required journalistic skill, nor the time free from scientific research to prepare adequate popular articles. Many journalists, while they can write in a way which is pleasing to, and easily understood by, the public, have not the background of scientific training to enable them to prepare adequate articles from the results of scientific growth.[7]

Clearly, it would be important to establish effective means of communicating the wildlife story in compelling terms to the public at large. Solman did not hesitate to use his own pen to promote the cause of wildlife conservation to groups that might not normally be expected to have an interest. That he did so with a keen sense of how to appeal to his audience was evident in an introductory editorial note that accompanied an article aimed at professional engineers. "A paper on wildlife may seem an unusual one for publication in the *Engineering Journal*," wrote the editor of the house organ of the Engineering Institute of Canada, "but...as Dr. Solman points out, the conservationist makes use of many engineering techniques."[8]

In his Dallas presentation, Solman was also able to point with justifiable pride to the growing array of posters and pamphlets that CWS was producing and distributing. In the year of his talk, these included 11 466 copies of the Migratory Birds Convention Act and Regulations; 58 040 copies (largely to hunters) of the regulations only; 32 748 posters; and 29 946 educational pamphlets. Among the latter, two of the most popular titles were "Bird Houses and Their Occupants" and "Attracting Birds with Food and Water."

These two were among the earliest forerunners of an initiative that became one of the greatest communications successes in CWS history. *Hinterland Who's Who* (*La faune de l'arrière-pays*), initiated in the mid-1960s by Darrell Eagles, head of CWS information and editorial services, is the longest-running series of wildlife information pamphlets in Canada. It must also be among the most extensive. The *Hinterland Who's Who* publications reached a peak in the 1970s. During that decade alone, 47 of the current 89 titles were released, always in both official languages. Although the rhythm of production has been somewhat slower in the 1980s and 1990s, it is an unusual year that does not see at least one or two new titles added to the list.

Over the years, subjects have broadened from the treatment of single species or families of birds and mammals to more general ecological themes: wetlands, estuaries, bird banding, endangered species. Each publication combines a text, frequently written by a CWS biologist with special knowledge of the topic, with photographs and illustrations to make an attractive four- or six-page folder. The style is simple and direct and assumes an intelligent interest on the part of the reader. School teachers and youth group leaders are among the many thousands of individuals who request copies annually to illustrate lessons, provide data for reports and projects, or simply learn more about the natural world around them. The enduring appeal of the *Hinterland Who's Who* folders is evident in their continued popularity now that they have been made accessible in electronic form via the CWS website.[9]

The success of the print version of *Hinterland Who's Who* was paralleled by that of a series of 60-second television clips bearing the same name. The Canadian Broadcasting Corporation had begun regular telecasting in 1956. As Canadian television found its stride in the years that followed, CWS Chief Bill Mair was struck by the potential of the new medium for communicating the message of wildlife conservation.

The annual celebration of National Wildlife Week provided just the opening that Mair needed. Out of respect for provincial jurisdiction in the field of education, the Federal–Provincial Wildlife Conference of that year recommended that Wildlife Week materials destined for classroom use be produced by a nongovernment organization, the Canadian Wildlife Federation. CWS, in cooperation with the provincial wildlife agencies, was given the task of selecting a common theme for each year's observance, around which to raise awareness among the general public.[10]

Mair passed the creative challenge over to Darrell Eagles, who developed the concept of a series of televised public service announcements that would introduce Canadians to a varied selection of their furred and feathered neighbours. He enlisted the aid of the National Film Board, a sister agency within the federal government that was already world renowned for the excellence of its films in celebration of Canada's natural heritage.

Eagles and coworker Graham Crabtree were determined that the brief clips should stand out from the mass of commercial television messages. Outstanding nature cinematography, informative, intelligent narration, and a distinctive musical theme gave the mini-documentaries a character that was instantly recognizable. For over 30 years, these brief "commercials for wildlife" have brought the fauna of Canada's woodlands, prairies, deserts, and wetlands to the attention of the national television audience. To date, 41 titles have been released, in English and French versions, to wide popular enjoyment. The quiet flute melody that accompanies them is one of the most widely identified musical themes on Canadian television today. The fact that the series has become a favourite target for affectionate parody by Canadian satirists and humorists is a good measure of the depth to which it has become rooted in Canadian popular culture.

Hinterland Who's Who was by no means the first CWS foray into the realm of audiovisual communications media. As early as 1949, CWS had embarked on a collaboration with the National Film Board to produce a series of educational films on birds. *Birds Near Home*, *Birds of the Seashore*, and a number of short films under the generic heading "Birds of Canada" presented brief portraits of the habits and habitat of a number of familiar species of birds.

At the same time, the National Film Board was producing numerous other films on wildlife subjects, either under its own mandate "to interpret Canada to Canadians and to other nations" or under the sponsorship of Parks Canada and other federal departments and agencies. Between 1947 and 1997, the National Film Board produced hundreds of films in which wildlife, ecology, and environmental conservation were dominant themes. Three outstanding titles in the early years were *World in a Marsh* (1956), *Spruce Bog: An Essay in Ecology* (1957), and *High Arctic: Life on the Land* (1958), all directed by Dalton Muir, a filmmaker whose interest in Canada's wildlife led him, eventually, to accept a position with CWS.

The impact of such productions, especially in a pre-television cultural environment, was significant. For many viewers, they sparked excitement and wonder about the ecological richness and diversity of their native land. More than a few young Canadians were drawn to careers in wildlife biology, nature photography, or environmental writing by what they glimpsed through these windows on the dynamic world of nature.

Close cooperation between CWS biologists and National Film Board filmmakers continued over the years. *Atonement* (1970) and an abridged version, *Keepers of Wildlife* (1971), documented the role of CWS in the context of species extinction and endangerment. In 1976, *A Great White Bird* reviewed the elaborate efforts to ensure the recovery of the

Right from the day it opened, the Wye Marsh Wildlife Interpretation Centre attracted a steady stream of visitors eager to learn about wetland ecosystems by actually spending time in one (Photo credit: D. Muir).

Whooping Crane. *Cry of the Gull* (1977) gave Canadians an insight into research into the effect of toxic contaminants on seabirds in the Great Lakes. As recently as 1997, a new National Film Board production entitled *The Barrens Quest* documented the ongoing search for evidence of a remnant breeding population of the Eskimo Curlew.

In a similar vein, the Canadian Broadcasting Corporation has drawn heavily on CWS expertise, since the advent of broadcast television, to inform and enhance public knowledge of wildlife and the environment through popular science series such as *The Nature of Things*. Much of the need for widespread environmental and wildlife education, identified so early by Lewis, Solman, and their colleagues, has been satisfied by the media of film and television in the intervening years.

As long as wildlife remains at risk, however, the task of educating the public will not be finished. As long as critical wildlife habitat is being converted to other short-term purposes and entire ecosystems are threatened by human agency, there will be a pressing need to promote public awareness of, and support for, conservation priorities.

This imperative was very much on David Munro's mind when he picked up the telephone one day in the spring of 1967 and dialled a number in Victoria, British Columbia. The Director of CWS, like his predecessors, was convinced that the conservation, research, and wildlife management initiatives of the service would be truly effective only to the degree that they were understood and approved by a broad spectrum of the populace. In that centennial year, he dreamed of establishing a professional interpretive program that would enable Canadians from sea to sea to learn about their wildlife heritage firsthand.

Munro was already familiar with the interpretive resources resident within the National Museum of Canada, as well as environmental education activities in national parks and in many provincial parks across the country. What he envisaged, as a complement to these, was a series of wildlife interpretive centres stretching from one end of the country to the other, each dedicated to displaying and explaining the functioning of the distinctive Canadian life zone in which it was located. Where possible, these centres would be situated in federal National Wildlife Areas, along or near the Trans-Canada Highway, and close to major population centres or target areas for vacation travel.

The person whom David Munro was calling on that spring day was Yorke Edwards, head of the highly successful interpretive services program in the provincial parks of British Columbia. For over a decade, Edwards had been involved in the conception, design, construction, and delivery of one of the best interpretive systems in North America. Munro had recently visited the "Nature House" in Manning Provincial Park and its satellite interpretation and activity sites. He had found both the concept and the execution exciting. Now, he was asking the man responsible to relocate to Ottawa and duplicate his achievement on a national basis.[11]

More than 20 years later, the Ontario-born Edwards, a wildlife biologist by training, wrote of Munro's invitation that:

> David dangled more bait than he knew. I was ready to experience again the northern hardwood region of my youth, with its scarlet tanagers and bloodroots, maple forests and winter redpolls. I also had a strong yen to know Canada better, coast to coast....So in September 1967, a few months after that first 'phone call, I arrived in Ottawa to take on a new job, pleased to be classified as a biologist while a bit embarrassed at the more specific title "Interpretation Specialist" on the door.[12]

Edwards agreed to devote five years to the task and no more. In that time, he established a philosophical foundation for CWS interpretive programs, explored and selected appropriate communications methods, plotted out the development of the first series of centres, and got one of them fully up and running before returning to the west coast.

By the time he had relocated from Victoria to Ottawa, work on the first wildlife centre was well under way. The chosen site was the Wye Marsh near Midland, in the heart of southern Ontario's vacation country. Situated at the southeast corner of Georgian Bay, just a few kilometres west of the Trans-Canada Highway, it was readily accessible to visitors. An incidental feature was its proximity to Ste-Marie-among-the-Hurons, one of the most popular heritage sites in the province. The Wye Marsh wildlife centre was built on an extensive wetland property adjacent to the reconstructed mission, so close that the two interpretive centres, one historical and the other ecological, shared a common access road.

It would have been hard to find a better site to demonstrate the characteristics of a rich, southern Ontario wetland. A widely representative variety of aquatic plants provided cover and food for a complex web of fauna, ranging from multitudes of freshwater invertebrates to large numbers of resident and migrating waterfowl. As a location in which to pursue the art of interpretation in the presence of wildlife, it was close to ideal. Even so, presenting the complexity and dynamism of the marsh community in a compelling manner to an audience comprised largely of casually curious visitors posed a major creative challenge. Happily, in the halcyon days of Canada's Centennial euphoria, budgets were generous enough to encourage innovation.

Yorke Edwards coordinated, planned, and supervised the development of the Wye Marsh facility single-handedly for several months before being joined by Bill Barkley, another British Columbia resident, who was sufficiently excited by the prospect of the new centre that he left his science classroom and moved to Midland in 1968. Together, the two charted a course through a maze of details and decisions ranging from the choosing of paint colours to the hiring of a decoy carver or the creation of a botanical inventory of the marsh.

Wye Marsh opened officially in 1970. In that first season, more than 10 000 visitors were logged in over the course of the summer. An additional 3000 came on school tours that fall. It was a promising start.

Certain decisions concerning the centre had been locked into place even before Edwards' arrival. The core building and adjacent parking area were functional but lacked aesthetic harmony with the site to which they would serve as gateway. This drawback could be mitigated somewhat by exterior landscaping and interior program content, but it could never be wholly undone. Therefore, Edwards and Barkley focused much of their attention on developing high-quality observation facilities to enhance the visitors' experience both indoors and out.

A viewing platform atop a substantial steel tower provided a vantage point above the dense wall of cattails, from which to observe the interplay of life in the marsh. A floating, sectional boardwalk enabled visitors and interpretive staff to walk, quite literally, on water. A video camera, focused on a bird's nest, delivered a closed-circuit image of the intimate interactions of adults and nestlings to a video monitor inside the interpretive centre. Another access point was the "water window," a heavy plate glass observation port set in a wall below the water level to afford viewers a glimpse of underwater life in the marsh.

With these aids to observation in place, the centre invited visitors to roam the site on self-guided nature trails or under the guidance of informed interpreters. Evening talks, slide shows, signage, indoor exhibits, and informative pamphlets rounded out an active interpretive program. Those who were too impatient to wait for the natural dramas of the marsh to unfold could repair to a comfortably appointed screening room to watch a film in which all the intensities of the life of wild creatures — competition and mating, birth and nurture, pursuit and capture — were condensed into a few skilfully edited minutes.

When, a year or two after the opening of the Wye Marsh wildlife centre, Edwards and Barkley undertook an extensive evaluation of the program in its initial seasons, they concluded that this introductory film, for all its popularity, might be as much a liability as an asset to the program. The concentrated compilation of peak wildlife observation experiences, although fascinating, created unrealistic expectations of what might be seen in real time from the boardwalk or the observation tower.

Other lessons were emerging from the interpretation experience as well. Traditional interpretive programs, conducted in the protected settings of provincial and national parks, tended to portray nature as if it were in a pristine state. The very mandate of the Wildlife Service, as an agency charged with the responsibility, among others, of managing the human uses of wildlife in a variety of contexts on public and private lands, meant that hunting and trapping and other "real world" impacts on wetland wildlife and habitats had to be presented in an even-handed manner.

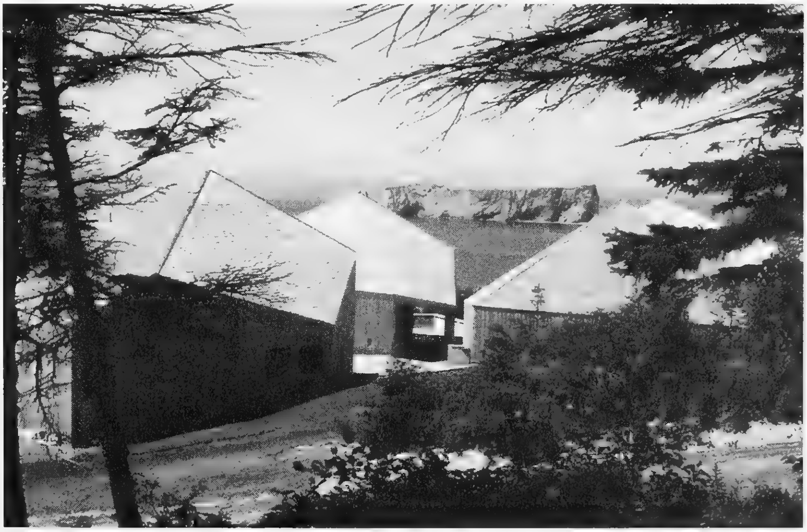
Another insight emerged from the formative years of the CWS interpretive program. The Wye Marsh wildlife centre had begun with the premise that the point of an indoor interpretive centre was to prepare visitors for an outdoor experience. With the benefit of hindsight, it seemed almost contradictory to bring people indoors to give them a message about the outdoors. On the other hand, the central building did serve a variety of practical purposes. It housed washrooms, workrooms, staff, and administrative facilities and provided shelter for the public when the weather turned hostile. In addition, it was a recognizable point of entry for visitors who needed some initial orientation in order to launch themselves into the visit. As Yorke Edwards recalls it, the enquiry led to an important moment of realization:

> Then came a thought that created a long and thoughtful silence: "Maybe we have the sequence of visitor experiences backwards. Perhaps the introduction should be a general orientation plus encouragement to enjoy a bit of the natural world which is in view for the first time. Reinforcing experiences should come after visitors explore the wild area. The beginning is not when [they] need answers from staff, exhibits, books,...films."[13]

Meanwhile, with Wye Marsh well established and a guiding interpretive philosophy emerging from hands-on experience, other links in the CWS wildlife interpretive network were also taking shape. It was intended that each major interpretive centre should offer an outstanding opportunity for observing and learning about a distinctive ecosystem or natural phenomenon. By the time the Wye Marsh wildlife centre had opened its doors to visitors, an impressive list of other candidate sites had been drawn up.

Among them was Cap Tourmente, about 50 kilometres downstream from Quebec City and renowned as an important spring and fall staging area for the Greater Snow Goose. The property combined two major ecosystems — estuarine salt marsh and northern hardwood forest — on a site of significance in the history of New France.

Cap Tourmente was the second CWS interpretive centre to become fully functional. In addition to its environmental importance as a staging area for waterfowl, it had other features to recommend it. Not least of these was its historical importance. The parcel of land in question was originally assembled under single ownership in the 17th century by Monseigneur François de Laval, first bishop of Quebec. It was he who secured it as part of the endowment of the *Séminaire du Québec*, which he founded in 1663. Ever interested in the education of the colony, Laval established the first trade



Sites for CWS wildlife interpretation centres were chosen with an eye to the scenic beauty of the location, and nowhere was this more true than at Percé, where the modular buildings on the hillside overlook the famous rock (Photo credit: C.-L. Gagnon).

school (*centre de formation en arts et métiers*) in Canada at one of the five farms that comprised the holding.

In the late 1960s, CWS biologist Marcel Laperle had identified Cap Tourmente as a target property for acquisition as a National Wildlife Area. Securing it was by no means a simple task. The seminary had indicated a readiness to liquidate some portion of its lands, though not necessarily the entire block, to raise capital for other projects. As a further complication, certain portions of the Cap Tourmente site were held under long-term lease by private hunting clubs. Bringing all the interested parties to the table required skilful diplomacy. One of the participants in the negotiation was Alan Loughrey, then Deputy Director of CWS. In his view, the influence of the Honourable Jean Chrétien, then Minister of Indian Affairs and Northern Development and the member of Cabinet to whom the Wildlife Service answered at the time, was invaluable. The purchase was concluded in 1969, using Parks Canada funds, but with management responsibility vested in CWS. "I've always felt badly that we didn't have a plaque or something recognizing [Chrétien's] contribution [in securing that property]," was Loughrey's comment in a 1996 conversation on the topic.[14]

By the end of 1971, Yorke Edwards' self-defined five-year term as head of interpretive services was drawing to a close. A lot had been accomplished. Under Marcel Laperle's dedicated supervision, construction of the Cap Tourmente wildlife centre, including careful restoration of some of the historic buildings, was nearly finished. Plans for an interpretive centre at Amherst Point, Nova Scotia, had been shelved, but another site had been secured at Percé, Quebec, overlooking Bonaventure Island, and architectural plans had been approved for a building cluster to house an interpretive program there.

Edwards was succeeded at the head of the interpretive program by Bill Barkley, who, over the next six years, oversaw completion of the two Quebec centres, as well as one in Creston Valley, British Columbia. Another, representing prairie habitat near Swift Current, Saskatchewan, was under development.

Bearing in mind the principle that the wildlife experience should come first and the interpretation afterwards, Bill Barkley sought to ensure that many of the ideas generated in the evaluation sessions at Wye Marsh would be incorporated in the Swift Current facility. It was no simple task. Unlike the other centres, this one, set on the bald prairie, had neither a breath-taking scenic focal point nor charismatic wildlife species to capture the attention of the travelling public.

The entrance featured a panoramic view of a prairie lake and surrounding grasslands. Strategically located spotting scopes invited new arrivals to become involved immediately in observation. A relief map indicated access trails into the meadows and around the lake. A door led visitors away from this entrance/orientation space and into the outdoors. Exterior signs, exhibits, marked trails, and a small guidebook all conspired to lead explorers through the wildlife area and eventually back to another part of the building, where books, additional exhibits, and trained staff were on hand to answer questions and assist in gaining an understanding of what had been seen.

Perhaps because of the momentum imparted by having two of five national wildlife centres within its boundaries after regionalization occurred in 1975–1976, the Quebec Region of CWS attached particular importance to the interpretive program. Headed by Jacqueline Vincent, the staff of the regional interpretive section grew to include six full-time and 15 seasonal positions. Credit for building the program to this scale belonged, in part, to Pierre Desmeules, CWS regional director for Quebec. Under the new regional structure, CWS regions had to compete with other departmental agencies and branches for increasingly limited resources. That so large an interpretive effort could be sustained reflected Desmeules' enthusiastic support and skill in dealing with the regional establishment of Environment Canada.

In the opinion of Jean Cinq-Mars, who served as Regional Director from 1984 to 1993, the interpretive program became one of the distinguishing characteristics of the Quebec Region.[15] To the two main centres, the region added smaller interpretive facilities at the Baie de l'Île Verte and Lac St-François National Wildlife Areas, as well as informative signage at other locations. Collaborative efforts with schools and other community-based organizations helped to extend the interpretive outreach.

The public, Quebecers and tourists alike, supported the centres enthusiastically. In 1972, its first year of operation, Cap Tourmente recorded 50 000 visitors. By 1984, visitation had grown to 100 000, so many that on busy days it was necessary to hire security officers to handle the bumper-to-bumper traffic. The Percé operation, despite its being off the main thoroughfare, was receiving over 30 000 visitors annually at its peak in the early 1980s, while 60 000 or more travelled each year to Bonaventure Island to view the gannet colony itself.[16]

Meanwhile, and wholly independent of the wildlife centres, a different kind of interpretive program was unfolding in a remote part of Quebec, far from the heavily travelled tourist routes. Starting about 1975, CWS entered into a constructive partnership with the Quebec–Labrador Foundation, a voluntary sector environmental organization with membership in both the United States and Canada. One of the principal objectives of the partnership

From the surrounding high ground it is easy to see why CWS Director David Munro felt that the Creston Valley in the British Columbia Interior would be ideal for a wildlife interpretation centre focused on wetland habitat (Photo credit: D. Muir).

was to enlist wildlife interpretation as a strategic tool in the struggle to reduce illegal harvesting of birds and eggs from eider and seabird colonies along the north shore of the Gulf of St. Lawrence.

Making use of CWS research facilities in former Transport Canada buildings at Îles Sainte Marie, Quebec–Labrador Foundation field staff conducted summer education camps for children from North Shore communities. They taught two central lessons: the importance of seabirds in the local ecosystem and the negative impact of human predation on seabirds. The net effect of the program was to instil conservation values into the families and communities of the poachers.

Gilles Chapdelaine, a CWS seabird biologist who has monitored seabird populations along the north shore regularly since 1975, feels that the Quebec–Labrador Foundation/CWS alliance has brought about a profound attitudinal change. Formerly, residents of the area actively resisted conservation initiatives; today, they actively favour wildlife protection. Poaching and egging have been reduced to a small fraction of the levels observed in the 1970s.[17]

In 1978, Bill Barkley was succeeded as head of interpretive services by Jim Foley. Foley, who had been working as an interpretation planning and evaluation specialist with Parks Canada, now fell heir to a fully operational network of five wildlife interpretation centres.

By this time, much of the impetus for further expansion of the network had dissipated. As a result of regionalization, the Research and Interpretation Branch no longer had direct authority over regional interpretive activities. In keeping with a pattern that applied equally to many other decentralized programs, Foley's job at the centre was to "provide functional guidance," a phrase signifying that he and his assistant, Roy Webster, were expected to motivate, coordinate, and provide a modest degree of program support across the five disparate regions. The zeal with which each region picked up the task appears to have varied according to the size of the interpretive commitment that it assumed and the extent to which the case for interpretation could be argued successfully before the Regional Director General of Environment Canada. Quebec, with two major wildlife centres and other regionally initiated interpretive activities in place, continued to attach a high priority to the program. The Atlantic Region, with no designated wildlife centre, added a single interpretive officer to develop signs and displays for National Wildlife Areas and to respond to public requests for talks and presentations.

Fortunately, the five operating centres were staffed with people who enjoyed their work and believed in its worth. In Quebec, Percé was headed by Réal Bisson and Cap Tourmente by Jean-Marc Coulombe. Bob Whittam managed the Wye Marsh facility, and Bob Peart ran the Prairie wildlife centre. Ralph Westendorp, initially in charge at the Creston Valley interpretive centre, had left by the time Foley began his new job and was succeeded by Rob Butler. Not only were these people first-rate interpreters themselves, but they had built a talented team of full- and part-time naturalists and interpreters to carry out the program. Lucie Lagueux, at Percé, was renowned as a storyteller. Jacques Sirois, who served as a seasonal interpreter at several locations, possessed a theatrical bent that was truly inspired. Faced with the challenge of explaining the biology of the Pronghorn Antelope to visitors at the Prairie wildlife centre, he devised an antelope costume and acted out the behaviour of the animal. In another season, at Percé, he put on a similar demonstration of gannet antics. Nor were these isolated examples. The creativity and dedication of the interpretive staff and the unique challenges and opportunities that their energy presented to the Ottawa head of the program were features that Jim Foley remembered fondly almost 20 years later.[18]

Creativity and ingenuity were needed in the early 1980s, as a hitherto buoyant Canada began to acknowledge the risks inherent in a perennial budget deficit. Tentative plans for continued expansion of the CWS interpretive program were shelved. Still, the need for interpretive services continued and the work went on, until November 1984.

When the Honourable Suzanne Blais-Grenier announced deep cuts to Environment Canada programs that fall, in keeping with the declared intentions of the newly elected Conservative government, many CWS activities were crippled. None was more thoroughly devastated, however, than the interpretive program. In a single stroke, the regional and headquarters interpretive units and all five wildlife centres were closed. In all, 32 person-years and $1.2 million assigned to interpretive work were wiped out, along with 50 person-years and $2.2 million allocated for wildlife research and two person-years and $0.4 million for habitat acquisition.[19]

Jean Cinq-Mars recalled the challenge of managing the cuts this way:

> I arrived at my new job with the Wildlife Service at the beginning of October. Within 6 weeks, I was faced with the cuts. My first meeting with many members of the regional staff was the meeting at which I had to tell them that their jobs were gone. I remember flying to Gaspé to fire the entire interpretive staff at Percé — 3 people whom I didn't even know. Seven more were slated for dismissal at Cap Tourmente. It was intolerable! I determined on that day that we would find a replacement job for each of them.
>
> As a first step, we negotiated the transfer of the Percé interpretive centre to the province, on condition that the staff would keep their jobs. At Cap Tourmente, we issued a call for proposals, seeking groups that might run that centre on our behalf. Eventually, the *Société Linnéenne* was selected. They would be permitted to charge admission and undertake other means of fundraising, but the deal was conditional on their being able to operate without requiring grants or subsidies from CWS. Unfortunately, they could not generate enough revenue to compensate our staff at the centre, so we had to find replacement jobs in Environment Canada and other federal departments. The arrangement with the *Société* worked quite well for about three years. Eventually, though, we chose not to renew the contract and resumed operation of the Cap Tourmente Wildlife Centre ourselves on a cost-recovery basis.[20]

In Ontario, the Prairies, and British Columbia, regional directors faced a similarly painful challenge and sought equally creative ways to preserve what they could of the interpretive centres. Operation of the Wye Marsh facility, widely recognized as a major environmental attraction in central Ontario, was turned over to a private, nonprofit organization. Bob Whittam laboured long and hard to establish and foster the "Friends of the Wye Marsh" and to secure resources that would enable the centre to remain open. Its continued success, more than a dozen years later, is cited as an excellent demonstration of what private/public sector partnerships can accomplish.[21]

In British Columbia, the Creston Valley Wildlife Management Authority, a joint federal/provincial/municipal alliance, already owned the 7200-hectare wetland on which the interpretive centre had been built. It was a relatively simple matter for that body to take over the building and seek funding from other partners, such as Ducks Unlimited (Canada), to support a modest program of activity.

The Prairie wildlife centre did not survive. Its failure can be attributed in part, perhaps, to the fact that it was the newest of the five and in part to its distance from any large metropolis where support for a partnership venture might have been generated. Several attempts at establishing such an organization to sustain it fell through. The site itself still benefits from protection as a National Wildlife Area, but the building has been sold and removed from the site.

Since 1984, with the exception of the Cap Tourmente centre in Quebec, interpretation has generally remained a peripheral activity within CWS. Staff do their best, on an individual basis, to respond constructively to requests for public presentations on environmental topics to school classes, fish and

Shortly before budget cuts forced the termination of the CWS interpretive program, Chiefs of the Wildlife Research and Interpretation Branch met at the National Wildlife Research Centre in Hull: (*front row, l. to r.*) G. Finney, W. Prescott, M. Lis, I. Price, J. Vincent, G. Scotter; (*back row*) C. Dauphiné, J. A. Keith (Branch Director), P. Whitehead, J. Foley (Photo credit: CWS).

game clubs, and other organizations. But the vision of David Munro, Yorke Edwards, and others, of a national network of interactive CWS sites where Canadians could encounter nature face to face, lies in abeyance. Passive exhibits, pamphlets, and interpretive signs enhance the experience of visitors to some conservation areas. A more active experience of nature awaits visitors to the Pacific and Yukon regional office, located in the Alaksen National Wildlife Area among the rich wetlands of the Fraser Delta, and to the Atlantic regional office in Sackville, New Brunswick, adjacent to the award-winning Sackville Waterfowl Park.

Nor was all its interpretive talent lost to CWS. In Vancouver, Rob Butler made a successful transition from interpretive officer to research scientist but retained a strong sense of the importance of good public relations. In 1985, he and R. Wayne Campbell of the provincial museum were engaged in a study of bird habitats in the Fraser River estuary. They determined that the area was used at various times of the year by some 300 species of birds from 20 countries on three continents and concluded in their CWS *Occasional Paper* that "there is no other site in Canada that supports the diversity and number of birds found in winter in the Fraser River delta."[22]

With little hope that the paper would have much influence, they nonetheless included a strong recommendation that key areas in the delta be afforded the highest forms of habitat protection, and when a reporter from the Vancouver *Sun* caught wind of the matter, Butler saw to it that he was fully informed. The tangled skein of media stories, court challenges, and political manoeuvrings that followed would require a chapter of their own to recount, but the outcome was clearcut and positive. In June 1995, British Columbia Premier Mike Harcourt announced, on the shores of Boundary Bay, that the bay was henceforth a Provincial Wildlife Management Area. As Butler tells it:

> Since our report was released in 1987, all of the recommendations on land acquisitions have come about. It was not because of our report alone — a very many people deserve the credit for pushing the issue and finding the funds to secure the habitat. In fact, Wayne and I did not really think we would get all of the recommendations we put forward. However, we are proud that the report findings, that continue to be cited today, had an important role in focusing attention on the protection of internationally important Boundary Bay — and it also shows the power of the pen (or keyboard).[23]

In the late 1980s, it appeared that an educational role of a different sort might be assigned to CWS. Canada's State of the Environment Reporting group was, for a brief time, housed within the Wildlife Service. During that time, a number of publications related to wildlife were released, including the book

On the Brink: Endangered Species in Canada (see Chapter 9). Within a year or two, however, the State of the Environment Reporting function was shifted to another part of the departmental organization chart, and by the mid-1990s, it had fallen victim to yet another budget-cutting exercise.

In retrospect, it is tempting to speculate as to why the CWS interpretive program was so vulnerable to the process of bureaucratic extinction. Granted, educating the public in the principles and values of conservation was never officially specified as a part of the agency's mandate. However, the Canada Wildlife Act (1973) does identify wildlife research, conservation, and interpretation as coequal priorities.[24] Certainly, it was evident to early leaders of the Wildlife Service, such as Harrison Lewis, Vic Solman, Bill Mair, and David Munro, that the struggle to conserve Canada's wildlife must be fought and won in the hearts and minds of Canadians. The interpretive efforts of the 1960s and 1970s contributed to an enormous surge in support for wildlife conservation — one that is apparent, even today, in the priority that many Canadians attach to the protection of species and spaces alike.

In 1991, a federal–provincial survey conducted by Statistics Canada indicated that some 18.9 million Canadians participated in one or more wildlife-related activities such as observation, photography, study, and feeding, as well as hunting and fishing. In the process, they accounted for economic transactions valued at about $5.6 billion. A majority (86.2%) stated their belief that it is important to maintain an abundance of wildlife.[25]

Reportedly, the public outcry that greeted the 1984 decision to shut down the CWS interpretive centres and greatly reduce wildlife research and management activities took the Minister's advisors by surprise. In that statement may lie one of the keys to understanding why such an unpopular measure was pursued with such determination. Yorke Edwards summarized the point this way:

> Those of us based in Ottawa failed to effectively interpret our program and to emphasize its successes to the civil servants and politicians above us. What little we did was probably nullified by the increasing comings and goings of ministers, deputy ministers and assistant deputy ministers...a high cost sort of administrative musical chairs [which means that] people high in federal governments see much less of their programs day to day, and hear less about them socially....Frequent and imaginative information must somehow flow upstairs. This should have been an interpretation priority equal to that of informing the public.[26]

The argument that inadequate internal promotion left the interpretive program vulnerable in a period of aggressive cost-cutting offers a rationale for the initial decision. It does not wholly account for the Minister's insistence on holding the line on the cuts despite the public outcry that followed.

On that issue, the government's point of view was best expressed by the Minister herself, on 20 December 1984, when she told the House of Commons Standing Committee on Fisheries and Forestry:

> As soon as we came to power, it was important to take immediate action if our efforts to reduce the debt and, of course, the servicing of the debt, were to be successful in the next fiscal year....
>
> To that end, our department adopted two guiding principles in reducing programmes and making the subsequent administrative cutbacks. The first principle was to stop the expansion of some programmes...and to redirect our efforts and energies toward the new environmental priorities set by this government. The other main guiding principle...is, of course, the awareness of our federal responsibilities. We are not the only ones who work in the environment. We are only one government. Each province has the tools, and very sophisticated ones at that, which enable it to implement measures within its own jurisdiction.[27]

A public that was becoming increasingly vocal in its support for wildlife and environmental conservation was not mollified by this argument. The unpopularity of the decision contributed to the demotion of Madame Blais-Grenier to the status of minister without portfolio in August 1985 and her ultimate disappearance from the Cabinet in June 1986. The public outcry could not succeed, however, in reinstating a program that Tony Keith, former Director of the Research and Interpretation Branch, described years later, in terms of its precise focus, regular evaluation, and excellent leadership and coordination, as being "the best managed CWS national program."[28]

Notes

1. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), pages 296ff.
2. Harrison F. Lewis, *Fifty Years of Progress and Handicaps in Wildlife Management in Canada* (Sackville, New Brunswick: Canadian Wildlife Service, Atlantic Region Library, unpublished manuscript, 1951).
3. V. E. F. Solman, *Our Urgent Need, a Conservation-minded Public*, unpublished text of a presentation to the International Association of Game, Fish, and Conservation Commissioners, Dallas, Texas, 12 September 1952 (Sackville, New Brunswick: Canadian Wildlife Service, Atlantic Region Library, 1952).
4. The first Occasional Paper was *Birds Protected in Canada under the Migratory Birds Convention Act.*
5. The first publication in the CWS Report Series was *Whooping Crane Population Dynamics on the Nesting Grounds, Wood Buffalo National Park, Northwest Territories, Canada*, by N. S. Novakowski.
6. The first of the CWS *Progress Notes* was Chuck

Jonkel's *Life History, Ecology and Biology of the Polar Bear*, published on 15 February 1967.
7. Solman, *Our Urgent Need.* (See note 3)
8. V. E. F. Solman, "Some aspects of conservation and wildlife management," reprint from *The Engineering Journal* (The Engineering Institute of Canada, May 1956).
9. Readers with Internet connections may access the CWS homepage at www.ec.gc.ca/cws-scf.
10. *Minutes and Papers of the 27th Federal–Provincial Wildlife Conference*, 18–19 April 1963, Ottawa (Ottawa: Canadian Wildlife Service, 1963), page 84.
11. D. A. Munro, personal communication, interviewed at Sydney, British Columbia, 30 November 1996.
12. Y. Edwards, "The Canadian Wildlife Service: interpreting across a continent," *Heritage Communicator* 2(3): 3–7 (1988).
13. Edwards, "The Canadian Wildlife Service." (See note 12)
14. A. Loughrey, personal communication, interviewed at Ottawa, 26 November 1996.
15. J. Cinq-Mars, personal communication, telephone interview, 12 April 1997.
16. J. Vincent, personal communication, interviewed at Quebec City, 25 March 1997.
17. G. Chapdelaine, personal communication, interviewed at Quebec City, 25 March 1997.
18. J. Foley, personal communication, interviewed at Ottawa, 25 November 1996.
19. Appendix "FIFO-2" to House of Commons, *Minutes of Proceedings and Evidence of the Standing Committee on Fisheries and Forestry*, Issue Number 7, 20 December 1984.
20. Cinq-Mars, personal communication. (See note 15)
21. Foley, personal communication. (See note 18)
22. R. W. Butler and R. W. Campbell, *The Birds of the Fraser River Delta: Populations, Ecology, and International Significance* (Ottawa: Canadian Wildlife Service Occasional Paper Number 65, 1987).
23. R. W. Butler, personal communication, 17 June 1998.
24. *An Act respecting wildlife in Canada*, Statutes of Canada, 21-22 Elizabeth II, Chapter 21 (Ottawa, 1973).
25. F. L. Filion, E. DuWors, P. Boxall, P. Bouchard, R. Reid, P. A. Gray, A. Bath, A. Jacquemot, and G. Legare, *The Importance of Wildlife to Canadians: Highlights of the 1991 Survey* (Ottawa: Environment Canada, Canadian Wildlife Service, 1993), page 51.
26. Edwards, " The Canadian Wildlife Service." (See note 12)
27. House of Commons, *Minutes of Proceedings and Evidence of the Standing Committee on Fisheries and Forestry,* Issue Number 7, 20 December 1984.
28. J. A. Keith, personal communication, 4 April 1997.

1977–1982: Consolidation

Had additional financial resources been available to sustain the growth of the reorganized CWS at the rhythm of a decade earlier, the inauguration of an expanded regional infrastructure and closer departmental links between CWS and other environmental agencies could have signalled the onset of a period of tremendous productivity. The habitat program was flourishing. Work on toxic contaminants was returning valuable dividends by identifying risks to wildlife and winning public support for corrective action. Tens of thousands of Canadians and visitors to Canada were learning about wildlife and wildlife management at four interactive CWS interpretive centres across the country, and plans for a fifth, which would open in 1980, were under way. The Wildlife Service had earned a role, which it was poised to play with increasing confidence, in national issues, such as aboriginal land claims and environmental impact review procedures. In addition, most of the provincial and territorial wildlife agencies, and a number of key nongovernment organizations as well, now had sufficient resources to enable them to be active partners in joint conservation ventures.

As it happened, however, this potentially exciting conjunction of interests and opportunities coincided with a marked downturn in the public perception of government spending. Concern about inflation had been a growing theme through the mid-1970s. Critics in business and the media had become increasingly vocal in their condemnation of government programs that displayed, at least in their view, an endless appetite for money.

It was in this climate of opinion that Treasury Board initiated an extensive program and budget review process. Environment Canada was one of the first departments to be subjected to this scrutiny. The stated objective of the so-called "A-base review" was to verify that all current programs were useful, were delivered efficiently, and fell within the federal mandate. Resources that were deemed to be "surplus" according to these criteria would be redeployed, though not necessarily within the agency to which they had been allocated.

The experience of having a lifetime's work assessed by outsiders who might have little appreciation of its nonmonetary value was demoralizing to the dedicated CWS staff, especially when coupled with the uncertainties of learning the ropes in a reorganized operating system. Many, whether scientists, technicians, or administrators, felt frustrated and disheartened by the situation, and it is hard to imagine that some programs did not lose momentum as a result.

The threat to morale motivated Director General Alan Loughrey to search for some symbol that would help to sustain the identity and cohesiveness of the Wildlife Service. An ad hoc committee established to select an appropriate icon recommended the loon;

however, when Loughrey proposed its adoption by CWS to the Deputy Minister, Blair Seaborn, the idea was rejected on the grounds that Environment Canada already had a corporate logo. Not to be put off, Loughrey then asked whether the loon might not be used to identify Migratory Bird Sanctuaries and National Wildlife Areas, and to this Seaborn agreed.[1] Although never officially sanctioned beyond that level, the blue loon symbol subsequently found its way onto the uniform hat badges of migratory bird enforcement officers, the covers of publications in the *Technical Reports* series, and the lapel pin issued to commemorate the 50th anniversary of the Wildlife Service. Clearly, it fulfilled Loughrey's intention to provide an identifying image around which CWS personnel and friends could rally during a time of organizational stress.

As it happened, CWS fared reasonably well in the review. Although a number of positions were declared surplus, most could be reassigned internally and were not lost. Where the Treasury Board analysis had its greatest impact was in a series of requests that "further consideration" be given to the following:

(1) [determining] how Migratory Bird Sanctuaries and National Wildlife Areas can be combined with other approaches to ensure adequate habitat protection;
(2) strengthening the economic perspective in wildlife programs;
(3) redefining guidelines for cooperative wildlife work under federal-provincial Canada Wildlife Act agreements, dealing with both the kind of work done and the formulae for cost-sharing;
(4) assessing the effectiveness of enforcement of Migratory Bird Regulations.[2]

The unwritten message was clear. Programs would no longer be supported on the strength of their worthiness alone. Henceforth, it would be equally important to demonstrate that they were being executed in a manner that minimized the need for federal spending while maximizing the potential for economic benefit. That was not an unreasonable expectation, nor one that CWS, long accustomed to accomplishing large tasks with small budgets, found distasteful. Indeed, the immediate reaction of the agency was to revise its 1977 priorities and extend its planning horizon to 1981.

Among the more important priorities and program adjustments that were highlighted in this exercise were a number that demonstrated proactive responses to the Treasury Board suggestions:

(1) to increase management efforts on existing National Wildlife Areas and improve public awareness of the areas through development of public information and wildlife interpretation programs;
(2) to develop a national waterfowl management plan, as a prelude to an attempt to work with the US Fish and Wildlife Service in developing a continental waterfowl management plan;
(3) to survey native harvests of migratory birds [in order to establish an adequate database on the native kill, an essential prerequisite to resolving the issue of native land claims and rights to hunt migratory birds];
(4) to help ameliorate the problem of crop damage by waterfowl to prairie grain crops;
(5) to establish an endangered species unit to design national programs, co-ordinate regional work, and maintain liaison with other agencies, and continue to support the work of the national Committee on the Status of Endangered Wildlife in Canada;
(6) to begin a study of the economic and social benefits of wildlife;
(7) to continue to preserve and protect critical wildlife habitat but develop alternate strategies to outright federal purchase of land.
(8) to improve capability for continuing previous initiatives on non-game migratory bird conservation efforts.[3]

Of the four Treasury Board requests, only the question of enforcement of the Migratory Game Birds Regulations was not addressed directly in this revision, and steps were already being taken, with the appointment of enforcement coordinators in the regions, to deal with it (see Chapter 2). Generally, over the next few years, the effort to consolidate CWS activities around these program priorities would lead to some of the agency's most important achievements.

The need to protect habitat through strategies other than outright purchase provided the impetus for exploring stewardship agreements and other forms of public–private sector partnership in the conservation of wetlands and other critical ecosystems. Although lands continued to be purchased for development as National Wildlife Areas, other means of securing them were actively pursued. In December 1977, for example, the six Canadian members of the Long Point Club, an exclusive, century-old hunting and fishing club on the north shore of Lake Erie, made a gift to Canada of 1000 hectares of marsh and dune habitat. Their action was historically significant as the first donation of lands to be made under the terms of the Canada Wildlife Act. At the same time, the 13 American members of the club contributed 2200 hectares to the Nature Conservancy in the United States, which the Conservancy later transferred to CWS for incorporation in a new, 3200-hectare National Wildlife Area.

The commitment to develop a national waterfowl management plan marked the beginning of a process that would culminate in implementation of NAWMP nine years later. During the course of the discussions and negotiations, a new organization, Wildlife Habitat Canada, would also emerge. The demand for a clearer linkage between wildlife work and economics provided rationale and support for the work that Fern Filion would lead over the next several years in designing and implementing a series of national surveys on the importance of wildlife to Canadians.[4] The survey instrument was completed in 1981, and the actual survey was conducted by Statistics Canada from February to May 1982.

Notes

1. Alan Loughrey, personal communication, letter to P. Logan dated 14 May 1998.
2. A. G. Loughrey, "Canadian Wildlife Service report" in *Transactions of the 42nd Federal–Provincial Wildlife Conference*, 27–30 June 1978, Quebec City (Ottawa: Canadian Wildlife Service, 1978), page 42.
3. Loughrey, "Canadian Wildlife Service report," page 43. (See note 2)
4. F. L. Filion, S. W. James, J.-L. Ducharme, W. Pepper, R. Reid, P. Boxall, and D. Teillet, *The Importance of Wildlife to Canadians: Highlights of the 1981 National Survey* (Ottawa: Canadian Wildlife Service, 1983).

CHAPTER 8. Wildlife Toxicology

New Responsibilities

For more than a dozen years after its establishment in 1947, CWS focused most of its energies on three broad tasks: administering and enforcing the Migratory Birds Convention Act; advising on the conservation and enhancement of wildlife resources within federal jurisdiction; and conducting field research on the diversity, biology, ecology, and behaviour of Canada's wildlife populations. By the early 1960s, however, there were disturbing signs that traditional conservation and research programs might no longer suffice. New threats to wildlife were emerging that would require new strategies and tactics.

One of the legacies of the Second World War was that a group of chemical compounds, developed or refined for military purposes, became available for widespread application in industrial and domestic settings. The spirit of the time encouraged uncritical acceptance of technological advances, and a variety of powerful pesticides (notably the insecticide DDT and the herbicides 2,4-D and 2,4,5-T) were enthusiastically adopted by farmers, foresters, public health officials, and backyard gardeners alike. Indeed, the Nobel Prize in Chemistry for 1948 was awarded to the Swiss scientist Paul Müller for having developed DDT, and the compound was widely recommended for use on food plants and as a means of controlling flies and mosquitoes in dwellings, barns, and public locations.

By the early 1950s, researchers with the United States Department of Agriculture reported an apparent connection between DDT and increased calf mortality, but it was not until late in the decade that links between the popular insecticide and the health of wildlife began to be widely noted. It is interesting to trace the increasing concern with which pesticides were viewed, as reflected in the wording of recommendations adopted by the Federal–Provincial Wildlife Conference. In 1953, delegates agreed:

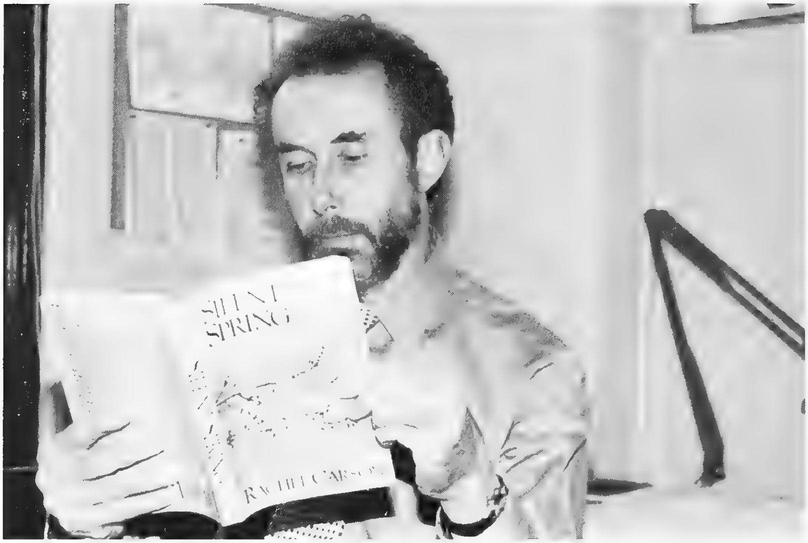
> that this Conference recommends that the appropriate federal department take the lead in bringing together manufacturers and users of chemicals and wildlife authorities with the objective of bringing about the greatest benefit from these chemicals with no damage to wildlife resources, or where this is not feasible, with as little damage as possible.[1]

Seven years later, the tone of pesticide discussions at the Wildlife Conference had changed noticeably:

> *WHEREAS* very discouraging reports are continually being received in respect to great damage being done to most if not all forms of wildlife, including the more or less uncontrolled use of various herbicides and insecticides,
>
> *THEREFORE BE IT RESOLVED* that immediate and appropriate action be taken by all game management agencies in Canada and the United States of America to thoroughly investigate and ascertain the actual effect on human life and wildlife in the use of these insecticides and to take, if found warranted, immediate steps to stop, modify, or in some way control the use thereof in order to ensure that said use will not be harmful to human life, wildlife, or fish.[2]

The following year, Dan Janzen, Director of the United States Bureau of Sport Fisheries and Wildlife, advised delegates to the federal–provincial gathering that researchers in his agency were finding "widespread evidence of pesticide residues in the tissues of [many wildlife species] ranging from minnows to deer." In his remarks, he cited studies involving game birds such as bobwhite and woodcock, as well as shrimp and shellfish, and concluded that "modern pesticides loom as a threat to many of our fish and wildlife resources."[3]

That the topic of pesticides was sensitive enough to evoke strong feelings is evident in the remarks of Henry Hurtig, who spoke to the same meeting on behalf of the Research Branch of the Canada Department of Agriculture. He took wildlife officials to task for allowing themselves to be influenced by "stepped-up, sensation-seeking publicity" about the risks of pesticide use. While acknowledging that "the wonderful tools of micro-chemistry" should be used with care, he was blunt in prescribing an economic rather than an ecological model for decision-making, and he argued that the determining principle should be "how much good will be achieved by the use of the chemical, weighed against the hazard involved in its use."[4] Indeed, almost four decades later, this is still the standard applied to pesticide registration decisions.[5]



Rachel Carson's book *Silent Spring*, published in 1962, awoke the public to the reality of chemical pollution of the environment and indirectly helped lay the foundation for the establishment of the Toxicology Division. Thirty years later, Tony Keith, the division's founder, still found the classic worth rereading (Photo credit: P. Mineau).

Nevertheless, a body of scientific evidence about pesticide residues was accumulating, and it pointed unmistakably to the conclusion that in many instances the hazard to wildlife was unacceptable. Within CWS, Vic Solman and Graham Cooch took the initiative to sensitize people to the issue and to lobby for action. In 1963, Solman reported on international findings that insecticides were contributing to reproductive failure among birds of prey.

> Although the CWS is not yet equipped to carry out the studies in Canada necessary to gather comparable data we believe it is a reasonable assumption that what is happening to wildlife in other countries as a result of chemical treatments in agricultural areas may well occur here.[6]

In 1964, Graham Cooch presented a paper entitled "Current developments in the biocide wildlife field," which summarized still more instances of pesticide damage. That year, the wildlife directors' conference adopted the following call for action:

> *WHEREAS* the danger to wildlife from the growing use of biocides has been of great concern to the agencies represented at this conference...
>
> *IT IS THEREFORE RECOMMENDED* that there be established a central agency for registration of information on residues in wildlife and that such information should be made available to anyone on request.[7]

Cooch acted on this recommendation to establish, under CWS auspices, what is now the National Registry of Toxic Chemical Residues. The venture depended on the Ontario Research Foundation laboratory to perform the chemical analyses; within 12 months, the registry contained the results of tests on over 2000 samples.

The fact remained, however, that Canada, a late starter in the study of pesticides and wildlife, was falling steadily farther behind. The very same products that had been shown to cause problems in the United States and Britain were in widespread use in Canada; yet, in spite of the growing urgency of the problem, neither Cooch nor Solman could afford to abandon other duties and make a full-time commitment to its solution. Therefore, when Cooch met a young man named Tony Keith at a NATO pesticides conference in Britain in 1965, it was a timely encounter. Keith had been working on his Master's degree at the University of Wisconsin, focusing on the effects of DDT on the reproductive success of Herring Gulls in Lake Michigan. The parallel between his research and the interests of CWS, especially in the Great Lakes region, encouraged Cooch to recruit him on the spot.

Initially, the pesticide program had a staff of two — Keith, and technician Stan Teeple — but the small staff was offset to a considerable degree by a generous budget. In the mid-1960s, CWS was entering a phase of rapid growth, fuelled by the government's decision to introduce a comprehensive national wildlife policy and by a burgeoning public interest in environmental concerns. Although the concept of environmental chemistry was new to the agency, CWS Director David Munro was supportive from the outset, and Keith was able to initiate or consolidate several projects at once.

The measurement of pesticide residues in the tissues of wild animals was already an established priority, and tissue analysis continued to be done for the next several years at the Ontario Research Foundation. An equally important part of the work was the creation of a central clearinghouse for information. Anyone seeking data on pesticide levels in a particular area could request it from the national registry. In addition, the unit gathered and distributed reprints on the subject from a wide range of foreign sources.

For the fledgling research group, the fact that other countries had been engaged in pesticide work for some time offered a definite advantage. Rather than having to invent a frame of reference, they found it helpful to be able to start right out looking for indications that problems already identified abroad might be present in Canada as well. They examined the effect on seed-eating birds and mammals of treating seed grains with insecticides and fungicides. They monitored the effect of orchard spray programs. They tested the eggs and tissues of fish-eating birds for indications of bioaccumulation of pesticides in the food web. And, by and large, they found patterns that were similar to those discovered by the research teams in other countries.

Another responsibility of the Pesticides Section was to participate in the review of pesticides that manufacturers submitted for registration or renewal by the Department of Agriculture under the Pest Control Products Act. As Tony Keith recalls it:

> We acted as ecological advisors in this work. We tried to build test information that went beyond looking solely at the risks to people working with chemicals, or people affected by pesticide residues on food, and to look at the effect of the compounds on the environment as a whole. And we made some progress in educating the agricultural community that there were potential issues here. But that occupied a good deal of time.[8]

As virtually the only advisors to the federal government on the subject of wildlife and pesticides, the group had a large responsibility. In the absence of broad environmental protection legislation or a mediating interdepartmental committee, Keith and his colleagues had to deal directly with a department — Agriculture — the mandate and priorities of which frequently ran counter to the best interests of wildlife. Fortunately, the Pesticides Section was not speaking for CWS alone. Tony Keith was in frequent communication with wildlife managers in every province and territory across the country and had their backing and support. In building his arguments, he also had a strong ally in the United States Fish and Wildlife Service. At the time, the United States Wildlife Research Centre at Patuxent, Maryland, was operating the top pesticide/wildlife review program in the world. Keith established a regular exchange of data with the American facility. Having access to that source of technical information and scientific backup enabled him to pressure Agriculture successfully about seed treatment and other controversial issues that he could hardly have hoped to document adequately using only the modest human resources of his own section.

From the outset, the new unit had a duty not only to discover the impact of pesticides on wildlife but to act to lessen it. The information gathered by the pesticides group would serve as ammunition for a proactive campaign to lobby for remedial action. Their efforts met with early success. Mercury was removed from use as a seed treatment, and the application of organochlorine insecticides on seed was strictly limited. Growing concern about the accumulation of organochlorine pesticide residues in birds of prey led Keith to arrange the transfer of biologist Richard W. Fyfe to the Western Region to assess the extent of this problem among raptors in Alberta and Saskatchewan (see Chapter 9). Evidence gathered in this and other CWS studies played a large part in the decision of the federal cabinet in 1969 to limit the use of DDT in Canada. In announcing restrictions that would cut consumption of the pesticide by about 90%, Prime Minister Pierre Elliot Trudeau made the point that:

> These [DDT] residues are mostly at low levels but have concentrated sufficiently in a few populations of birds and fish to cause reproductive failures and the elimination of a few bird populations over large parts of their normal range.[9]

The officially defined role of the Wildlife Service was scarcely broad enough to support such an activist role on its own. However, by their endorsement of federal initiatives in this field, as expressed at the 1964 Federal–Provincial Wildlife Conference, the provinces had effectively mandated CWS to represent their interests on matters pertaining to pesticides and wildlife ecology. The Wildlife Service was only a small agency charged with very specific duties in relation to migratory birds, yet provincial backing enabled it to speak to broader ecosystem interests when the question of pesticides arose in the context of large, economically important sectors such as agriculture and forestry.

The Thirty Years' War: Forest Pest Control, 1965–1995

The forest industry was a leading user of pesticides in eastern Canada. In the early 1950s, when vast areas of coniferous forest came under attack by the Spruce Budworm, authorities in Newfoundland, Quebec, and Ontario mounted extensive aerial spray programs. It was the Province of New Brunswick, however, that launched the largest, the longest, and

Painstaking fieldwork was required to demonstrate the harmful effects of the pesticide fenitrothion on forest songbirds. This picture was taken during the summer of 1979 while Peter Pearce (*l.*) and two assistants were measuring the growth rate of nestlings in a control plot (Photo credit: P. Barkhouse).

arguably the most controversial forest pest control program in Canadian history. Starting in the spring of 1952, squadrons of spray planes blanketed the spruce and Balsam Fir forests of the province annually with DDT. The application reduced but did not eliminate the voracious hordes of Spruce Budworm caterpillars. It also killed a wide variety of other forest and aquatic invertebrates.

Did this constitute a hazard to wildlife? Evidence was mounting that DDT had a negative effect on the health and productivity of raptorial and fish-eating birds. By the early 1960s, a search had begun for other chemical pesticides that would be less damaging to wildlife. In 1963 and 1964, a cholinesterase-inhibiting organophosphate compound called phosphamidon was field tested in New Brunswick. Early indications were that it was less harmful than DDT to nontargeted species, while still effective against the budworm.[10]

In 1964, Graham Cooch enlisted David Fowle and two of his graduate students at York University to undertake an in-depth assessment of the impact of phosphamidon on wildlife. Peter A. Pearce, then an employee of the Timber Management Branch of the New Brunswick Department of Lands and Mines, was seconded by the province to work with them. What Fowle and his team found that summer[11] was enough to justify continuation of CWS support for the project over the next three years. By 1967, CWS hired Peter Pearce to work full-time on the project. Forest insect sprays were the principal focus of his work for the next 25 years.

Fowle's report on the four-year study confirmed that operational use of phosphamidon for Spruce Budworm control could indeed be hazardous to birds.[12] However, the statistical tables and carefully couched scientific language did not convey the full extent of that hazard. In later years, Peter Pearce would recall, "The eerie stillness of a forest sprayed with phosphamidon was, for me, the true visitation of a 'silent spring.' It is etched indelibly in my memory."[13]

By the end of the 1960s, the documentation of massive fish kills, the near-extinction of the Peregrine Falcon, and many other indications of serious environmental contamination had spelled the end for DDT as an acceptable pest control product. Other chemical pesticides, such as phosphamidon and aminocarb, had been tried in the budworm campaign and found wanting. Ultimately, the choice of forest managers fell on fenitrothion, another cholinesterase-inhibiting organophosphate compound that disrupts normal functioning of the brain and nervous system.

Fenitrothion seemed like an attractive choice. Testing indicated that it was less persistent in the environment than DDT and less acutely toxic to birds than phosphamidon. It had been approved for use as early as 1967 and became the standard budworm control agent in New Brunswick by 1970. Eventually, it came into wide use throughout eastern Canada to combat both the budworm and another larval insect pest, the Hemlock Looper. Still, these facts did not prove that fenitrothion was harmless to

When forest spray planes were operating overhead, Nev Garrity would don the latest in protective "spray wear" to avoid inhaling the toxic droplets (Photo credit: D. Busby).

wildlife. Peter Pearce and Neville (Nev) Garrity spent most of the 1970s gathering evidence that songbird populations were suffering in areas that were treated with the "safer" insecticide.[14]

The targeted area was enormous. Between 1975 and 1986, an average of 1.76 million hectares of New Brunswick forest were sprayed annually. Pearce and Garrity were joined in 1978 by Dan Busby, fresh from completing a Master's degree in ornithology at the University of Manitoba. Expansion of the team provided an opportunity to apply more sophisticated research methods to the problem. As Pearce and Busby pursued their own investigations and called on the resources of the CWS Toxic Chemicals Division in Ottawa as well, the hard evidence that would ultimately convict fenitrothion began to mount. As Busby put it later, "We didn't expose fenitrothion as the cause of a calamity. We just found a whole lot of good reasons not to use it."[15]

Their research revealed a complex puzzle with many pieces. For example, tissue testing indicated significant inhibition of brain cholinesterase activity in many of the exposed birds — not enough to kill them all, but enough to cause abnormal behaviours such as loss of coordination and nest abandonment in many that did not die.[16] A study of breeding White-throated Sparrows showed that the rate of reproductive success in territories subjected to the spray was little more than one-quarter of that in unsprayed control plots.[17] Warblers, thrushes, finches: all were affected to a noticeable degree, and beyond that there were other disturbing findings. Tests of fenitrothion in running streams had suggested a rapid rate of breakdown; research in still waters revealed that traces persisted in bottom sediments a year after application.[18] Other reports indicated high rates of mortality among insect pollinators[19] and significant effects on some aquatic invertebrates.[20] In 1989, the Pesticide Issues Team of Environment Canada published a comprehensive summary of the research, citing more than 500 reports as evidence that there were, at the very least, serious grounds to question the suitability of fenitrothion for use on Canadian forests.[21]

Regulations under the Pest Control Products Act at the time empowered the Minister of Agriculture to suspend registration of a product if it posed an unacceptable risk to plants, animals, or the environment. The findings put forward by the Pesticide Issues Team moved Agriculture Canada to call, in 1990, for a formal review of fenitrothion. A discussion document was released early in 1993, and in 1995 a ministerial decision was announced that the most thoroughly researched pesticide in Canadian history would no longer be registered for use in aerial spray programs to protect forests against the Spruce Budworm.

Broadening Horizons — 1965–1970

Although CWS entered the field of toxicology in response to concerns about pesticides, the scope of its interest soon broadened to address the effect of other toxic substances on wildlife. In Sweden, mercury had proved to be an environmentally troublesome metal. Not only was it an incidental poison for birds when used as a seed treatment, but it also contaminated fish and fish habitat when released in effluent from pulp mills, where it was used in the chlor-alkali process. A review of mercury sales to the Canadian pulp and paper industry indicated that significant amounts of elemental mercury were being lost to the environment annually in Canada.

In 1968, Tony Keith assigned the task of defining and evaluating the extent of mercury hazards to wildlife in Canada to a doctoral student from Norway named Norvald Fimreite, who was familiar with the Swedish literature. As in Europe, mercury was being released into the Canadian environment from two main sources: agriculture, where mercury-based fungicides were applied to seed grains; and forestry, where the metal was discharged into water by the pulp and paper industry.

In connection with the use of organic mercury compounds as seed-dressings, Fimreite found elevated levels of mercury in the livers of seed-eating birds and of the bird-eating falcons and accipiters that preyed on them. When his findings were compared with the data that Richard Fyfe had gathered on prairie raptors,[22] they pointed to a significant likelihood that the bioaccumulation of mercury in bird-eating species, combined with the effect of organochlorine compounds such as DDT and DDE, was contributing to the alarming levels of reproductive failure and population decline in these birds of prey.[23]

The review of the Swedish literature had pointed to similar declines in fish-eating species such as the White-tailed Eagle, in which the problem was linked to the use of mercury by the forest products industry. In Canada, Fimreite's exploratory examination of fish samples taken in waters downstream from pulp mills indicated the presence of high residual levels of mercury. CWS biologist Kees Vermeer joined the toxicology team at this point to accelerate the assessment of mercury from Canada's largest industry as a hazard to fish and to fish-eating birds. The study of contaminants in this sector of the food chain was to be a recurring theme throughout much of Vermeer's career, whether in the Great Lakes, across the Prairies, or along the Pacific coast. Meanwhile, an ongoing series of research projects demonstrated that mercury posed a significant threat to wildlife in many locations. To cite one example, a study by Jack F. Barr on the impact on Common Loon reproduction in the English-Wabigoon River system in northwestern Ontario proved to be a landmark piece of research. By comparing data from lakes that were receiving mercury pollution from a distant pulp mill and other lakes that were isolated from the pollution stream, Barr demonstrated a direct link between the presence of mercury and diminished reproductive success among loons.[24]

Recognition of how complex the web of chemical hazards to wildlife might be was augmented by the discovery of organochlorine compounds other than DDT and its metabolites in tissue samples. These were PCBs, a chemical group that had been identified initially by Swedish scientists whose techniques Lincoln Reynolds adapted for use in his lab at the Ontario Research Foundation. Although the PCBs were not pesticides, their chemical similarity suggested that they might also be damaging to living organisms. To test this hypothesis, CWS initiated other lines of research.

At about the same time that Fimreite was beginning his work in northwestern Ontario, another investigation was getting under way in Atlantic Canada. Keith was generally reluctant to commit valuable resources to routine monitoring, on the grounds that the more urgent priority was to uncover or understand immediate problems. Nonetheless, in 1968, as CWS began to broaden its interest in seabirds and other species besides migratory game birds, he supported an initiative by Peter Pearce to begin measuring organochlorine contaminants, including PCBs, in the eggs of three seabird species — Double-crested Cormorant, Leach's Storm-Petrel, and Atlantic Puffin. Eggs were collected at four-year intervals from sites in Newfoundland, in the St. Lawrence estuary, and in the Bay of Fundy. In 1985, a parallel CWS program was instituted in the Pacific and Yukon Region, with eggs being taken from sites in the Strait of Georgia, on the west coast of Vancouver Island, in Hecate Strait, and on the Queen Charlotte Islands. Samples were also collected in the high Arctic. While contaminants varied in type and quantity from one location to another, the data generated by these monitoring efforts demonstrated that none of the test areas was free of contamination.

The presence of contaminants in aquatic ecosystems throughout Canada underlined one particularly difficult aspect of dealing with stable toxic compounds. Clearly, they were not staying in one place. Rather, they were dispersing readily and widely through air, water, and the food chain. When researchers from various nations started finding residues of DDT and other toxic substances in the tissue of predators in areas as distant from industrial sources as the north and south polar regions, it became uncomfortably evident that the contamination was global and called for worldwide solutions. Concern about the economic impact of environmental problems led the OECD to establish an Environment Committee. The committee promptly set up a Sector Group on the Unintended Occurrence of Chemicals in the Environment. Tony Keith was elected to chair this group, which succeeded in getting the OECD Council to approve the first international agreements to limit the release of mercury and PCBs into the environment.

The link with the OECD continued to be vital and valuable when David B. Peakall succeeded Keith at the meetings in 1978. One of Peakall's most important achievements in this context was his work to establish international recognition of certain common standards for the regulation and approval of new pesticides. The adoption of "Minimum Pre-market Data" criteria went a long way towards reducing the need for the repetition of basic testing in every country in which a product was proposed for use. Peakall's involvement with the OECD lasted until his retirement in 1990, when Pierre Mineau and others in his section took on the responsibility.

An operational pattern had been set during the introductory years of toxic contaminant research that combined proactive exploratory fieldwork with reviews of pesticide products proposed for registration and the gathering and dissemination of current information on toxic contaminants in wildlife and wildlife habitat. Some initial battles had been fought and won, and, as the federal government moved to consolidate environmental agencies within a single, integrated department, funding became available for expansion of key functions. The stage was being set for greater challenges yet to come.

One of the first came with the decision that CWS would set up its own tissue analysis lab. This facility opened in 1971, sharing space with the pathology and parasitology group in a building in the Ottawa suburb of Vanier. It was initially headed by Gerry Bowes, with Michael Mulvihill as technologist. Bowes was succeeded in 1973 by Ross Norstrom. On transferring to CWS from the Biological Sciences Division of the National Research Council, Norstrom wrote to the regional directors inviting their suggestions as to what issues should get priority treatment by the new lab. Perhaps because toxicology was still an unfamiliar field to most wildlife biologists, the response was, in Norstrom's words, "a rather resounding silence."[25] He then set about trying to define his role within his own perception of how CWS could contribute to toxic chemicals and wildlife issues within the agency. Norstrom took action to build up the capability of the unit by recruiting a chemist, Henry Won. Over the next 25 years, the Chemistry Section played a key role in hundreds of investigations into the presence of toxic contaminants in wildlife.

As the scope and complexity of the challenge became more evident, Tony Keith was able to secure additional resources to expand the Toxic Chemicals team. A critically important relationship began in 1972, when David Peakall applied to CWS for a research scientist's position in toxicology. Peakall had been working at Cornell University for several years, exploring the physiological action of persistent environmental chemicals — organochlorine pesticides, PCBs, and heavy metals in particular — on birds. His testimony before hearings into the effects of DDT contributed to getting that pesticide banned in the United States, and his extensive work on pesticide-related eggshell thinning in doves, ducks, and raptors was complementary to Richard Fyfe's fieldwork on Peregrine Falcons.

Peakall had already carried out studies that showed the global nature of eggshell thinning in the Peregrine Falcon and demonstrated that this was caused by DDE, the major breakdown product of the insecticide DDT. The fact that he had also directed the Cornell nest record card program since its inception made him a particularly attractive candidate for an agency that was primarily concerned with the broader aspects of migratory bird conservation and protection. Three years would pass before he became a full-time resident of Canada, but he travelled frequently to Ottawa, playing a significant role in setting priorities for the Toxic Chemicals Section.

In 1975, the wildlife pathology and toxicology laboratories relocated from their now-cramped quarters in Vanier to the laboratory building and surrounding property that had been vacated by the Animal Diseases Research Institute in Hull, near CWS headquarters. The following year, the property was established as the National Wildlife Research Centre and included the headquarters of the interpretation program as well as the toxicology, pathology, and bioelectronics units. Tony Keith was the founding director and remained in that post until his retirement in 1996.

Engaged in seabird contamination studies on the Great Lakes during the 1970s, Stan Teeple examines the wing of a Caspian Tern on Cousins Island, North Channel, Lake Huron, in June 1978 (Photo credit: H. Blokpoel).

Toxic Chemicals in the Great Lakes

The probability that wildlife in the Canadian Great Lakes might be seriously affected by toxic contaminants had been demonstrated by Michael Gilbertson, starting as early as 1969. Assisted by Stan Teeple, he documented a disturbing lack of reproductive success among Herring Gulls at colonies in the lower Great Lakes.[26] Gilbertson continued to work in this field, and, with the signing of the Canada–USA Great Lakes Water Quality Agreement in 1974, resources became available to expand the team.

With David Peakall established as Division Chief in 1975, Glen A. Fox, A. P. (Andy) Gilman, and

Since the early 1970s, seabird studies on the Great Lakes have been inextricably, though not exclusively, linked to the tracking of toxic contaminants in the environment. Chip Weseloh, seen here banding cormorants on Talon Rock, Lake Huron, in 1979, was engaged in this research from the outset (Photo credit: P. Mineau).

D. J. (Doug) Hallett formed the nucleus of an Ottawa-based group that concentrated much of its effort over the next few years on monitoring the quality of Herring Gull eggs as indicators of environmental health in the Great Lakes. Their efforts were complemented by the recruitment, in 1978, of Chip Weseloh and Pierre Mineau to work on the Great Lakes Program within the Ontario Region. Much of the focus of their work was on persistent bioaccumulatory organochlorines such as DDT, dieldrin, and PCBs, and on whether or not the levels of these substances in the environment were declining in response to pollution abatement measures that had been introduced in the late 1960s. They were also given the task of identifying and exploring the biological consequences of those contaminant levels, following on the pioneering work of Gilbertson, Fox, and Gilman. In this respect, it is worth noting that CWS was hiring two biologists with expertise in behavioural and reproductive studies, specifically to extend the scope of the research beyond the simple monitoring of contaminant levels. Meanwhile, in addition to managing analytical contracts with the Ontario Research Foundation, supervising the growing capacity for chemical analysis within CWS, and doing much of the chemistry associated with the Great Lakes work, Ross Norstrom turned his attention to developing bioaccumulation models in gulls and other birds.

The Great Lakes, and Lake Ontario in particular, provided an ideal opportunity for the study of toxic contaminants, if only because so many were present in the water, the sediments, and the food pyramid. Through the process of bioaccumulation, concentrations of many persistent contaminants increased with each level of the pyramid, producing, in the Great Lakes, toxic effects in the large fish and fish-eating birds and mammals at the apex. Indeed, the Great Lakes Program found tissue samples from top predators captured in Lake Ontario and Lake Michigan to be among the most heavily contaminated in the world.[27]

Eggs were the preferred source of sample material for a number of reasons. They were relatively easy to collect, did not require the killing of adult birds, and were usually replaceable by the nesting females if taken early in the season. The Herring Gull was the principal species chosen for monitoring because it was widely distributed among the five lakes, and, since adults remained on the Great Lakes all year round, they were unlikely to be importing contaminants from sources outside the region. After controls had been imposed on the use of a number of organochlorine chemicals in the late 1960s and early 1970s, the Herring Gull monitoring program provided a means of measuring improvement, and, indeed, Herring Gull reproductive success did rebound rapidly, from a very low level in

1975 to something very close to the historical norm by 1978.[28]

Herring Gulls were by no means the only creatures monitored under the Great Lakes Program. Other species studied at various times and for various purposes included Black-crowned Night-Heron, Bald Eagle, Ring-billed Gull, Common Tern, Forster's Tern, Caspian Tern, and Common Snapping Turtle.[29] Tracking of the Double-crested Cormorant population of Lake Ontario demonstrated a decline almost to the point of extirpation because of eggshell thinning as a result of DDE contamination.[30] Studies of colonies in Georgian Bay in 1972 and 1973 found that 95% of eggs broke within four days of laying.[31] As DDE faded from the ecosystem, the cormorant population recovered at a phenomenal rate, from about 100 pairs in the early 1970s to more than 30 000 by 1993. Continued monitoring of cormorant colonies revealed new problems, however, in the form of crossed bills, club feet, and a variety of other congenital deformities that appeared to stem from PCB contamination.[32]

Repositioning in the 1980s

In the spring of 1980, David Peakall undertook a new research initiative to examine sublethal effects of crude oil ingestion on waterfowl and seabirds. This was a topic of growing concern. Offshore oil and gas developments were gaining momentum in Newfoundland, and there was an evident need for ways to assess their impact on wildlife. The devastating effects of oil spills on seabirds had long been known, but Peakall focused mainly on the sublethal effects of small doses of crude oil. The most extensive study was carried out on Leach's Storm-Petrel at the large colony on Great Island, Newfoundland. Three years of data revealed that although a modest exposure to oil reduced breeding success, it did not affect the percentage of adults that returned in subsequent years or their reproduction in the second season after exposure.[33]

One member of this team was Ted Leighton, who was trained in veterinary medicine. Thus, for the first time since the loss of the Wildlife Pathology Division in 1985, this discipline was once more involved in CWS research. One important consequence of this was that Leighton maintained his association with CWS after he joined the Department of Veterinary Pathology at the University of Saskatchewan. He was instrumental in setting up the Canadian Cooperative Wildlife Health Centre, which now has units at all four veterinary colleges in Canada.

Another environmental topic that was attracting public attention at this time was the threat of acid rain. Across much of eastern Canada, there was concern that airborne acidic pollutants from distant industrial sources were having an adverse effect on vegetation, soils, and water bodies that lay in their path. More than 700 000 lakes were receiving acidic deposition above background levels.[34]

An early warning of this risk had been sounded in the Atlantic Region in 1977 by CWS limnologist Joe Kerekes (see Chapter 5),[35] and by 1980 CWS had launched a research program to assess the significance of the long-range transport of airborne pollutants (LRTAP) on wildlife and wildlife habitats in affected areas. One important objective was to compare the breeding and feeding ecology of birds in areas receiving different amounts of acidic precipitation. Initially, research was conducted in Ontario[36] and Quebec.[37] The accumulation of data from these and other focused studies led to development of a multi-partnered LRTAP Biomonitoring Program coordinated by CWS through the National Wildlife Research Centre. Coordinators were Kathleen (Kathy) Fischer followed by Tony Diamond and then Peter Blancher. David Peakall was scientific advisor. The purpose was to track changes in a wide selection of sensitive aquatic ecosystems and to evaluate the adequacy of emission control programs. In addition, Peter Blancher at the National Wildlife Research Centre worked closely with the Ontario regional study group to develop computer modelling techniques that would be applicable to the monitoring effort.[38]

Frequent organizational reshuffling during this period reflected both economic and scientific influences. The halcyon days of growth that had characterized public sector programs in the late 1960s and early 1970s had been replaced by a reductionist trend in political and administrative thinking. Downsizing and privatization became fashionable concepts as the "baby boom" generation assumed positions of power and influence in government, business, and the media.

On the other hand, the 1970s and 1980s saw an increasing diversification of scientific resources in Canada. CWS had been the pioneering agency in many aspects of Canadian wildlife research. Now, provincial, institutional, corporate, and volunteer sectors possessed significant capabilities of their own. To take a single example, when CWS established the Registry of Pesticide Residues in 1964, it was the only Canadian organization that was really in a good position to provide such a central reference bank for users across the country. Twenty years later, this was no longer the case, and the registry, while still significant, was by no means unique. As in many other areas of wildlife conservation, protection, and management, the national role of CWS in toxicology was shifting from central to complementary and collaborative, vis-à-vis other participants in the field.

One positive offshoot of this development was the establishment, in 1985, of the Wildlife Toxicology Fund. The deep budget cuts announced by Environment Minister Suzanne Blais-Grenier in November 1984 dealt a severe blow to in-house research at CWS. The Pathology Section was completely eliminated, and many research scientists in other fields lost their jobs or were transferred to different duties. The potential setback to wildlife toxicology work in Canada was alarming to voluntary environmental organizations. The World Wildlife Fund (Canada) challenged the federal government to match funds, dollar for dollar, with the nongovernment sector to establish a program that would support toxicology research projects initiated by scientists at Canadian universities. A board was set up with delegates from the partnering organizations under the chairmanship of Donald Chant, a professor at the University of Toronto and the head of Pollution Probe. David Peakall was the CWS representative to the board of the fund for several years and was succeeded in this role by W. Keith Marshall. The Wildlife Toxicology Fund continued to invest in promising research projects for 12 years, until its termination in 1997.

While new partnerships were being developed to promote nongovernment research, certain core functions of the CWS toxicology group were also being strengthened. Studies on the use and impact of pesticides, as well as the review of new pest control products, continued to occupy an important part of the resources of the toxic chemicals group. At its head, Keith Marshall was very conscious of the role that CWS could play, as plans were advanced to replace the Environmental Contaminants Act (repealed in 1985) with the Canadian Environmental Protection Act (1988). Representing CWS in the discussions leading to the drafting and passage of the new legislation, he argued tenaciously for acknowledging the importance of CWS/Environment Canada roles in researching the presence of toxic chemicals in ecosystems and regulating a wide group of substances.

When Doug Forsyth left his position as the sole CWS pesticide evaluator in 1982 to become the pesticide specialist in Saskatoon, Pierre Mineau took up the challenge. Problems he encountered included the impatience of the pesticide manufacturers to obtain approval of their products and pressure from the Canadian Council of Resource and Environment Ministers to register a greater number of pesticides for use in forestry. The reasoning of the Canadian Council of Resource and Environment Ministers was that if a large array of products could be made available to farmers, then a comparable range of choices should be accessible for use in forest management. Their puzzlement was indicative of a widespread belief that forestry was essentially a large-scale form of farming and should have the same chemical tools to work with. The attitude was a fair reflection of an economic philosophy that equated trees with fibre but ignored the question of a forest's greater ecological complexity.

Now, in the mid-1980s, the demands of industry, a more environmentally aware public, and new legislative initiatives all supported the allocation of additional positions to pesticide evaluation. The task would henceforth be addressed by an entire section rather than a single person. The expansion made it possible not only to accelerate the administrative review process, but to initiate independent investigations as well. An early example focused on diazinon, a poison widely used on golf courses to control Chinch Bugs and other pests. Migrating waterfowl grazing on greens and fairways that had been treated with the substance were dying in significant numbers. When the United States Environmental Protection Agency announced a review of the product, Mineau was invited to assist in building the case. The justification for his involvement, from the CWS standpoint, was clear. The waterfowl in question might be dying in the United States, but they were Canadian-bred birds.[39]

The diazinon experience, in which the onus was on the scientists to demonstrate that a hazard posed by an approved product was too great to be acceptable, demonstrated the importance of pushing research beyond a simple review of industry data. Too often that information, while accurate in terms of the testing required for registration, did not address all the potential hazards. Conventional pesticide testing by or on behalf of industry sought evidence that a new compound would be safer for mammals and more deadly for insects — that, for example, a substance was harmless to rats but killed cockroaches on contact. Such a narrow model overlooked the fact that responses to exposure may vary widely among different wildlife species.

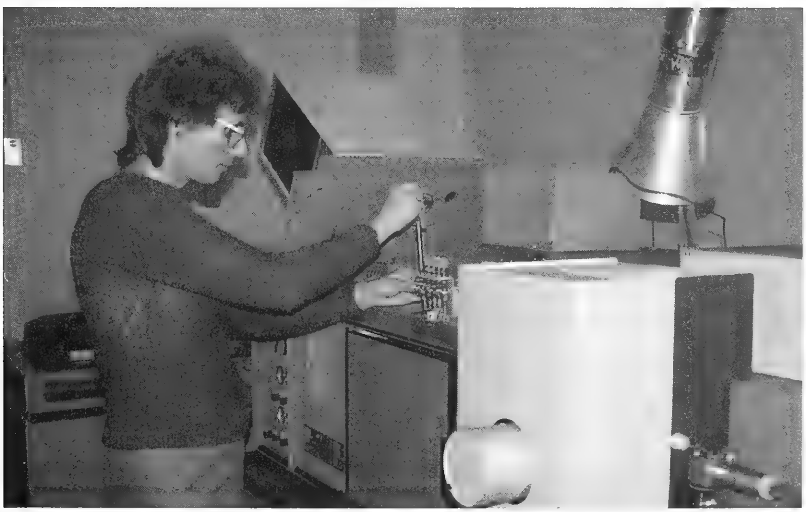
Having sufficient resources to pursue independent research enabled the Pesticides Section to take a more holistic view of pesticides and the environment. They extended their research to include such diverse areas as determining how pesticides affect bird behaviour and reproduction, mapping areas of high pesticide risk for species that migrate from Canada to Latin America, protecting plants in field borders, assessing the ability of birds to control insect pests, and looking into amphibian and bird population declines in farmland. In the southern Prairies, for example, Glen Fox and Pierre Mineau, with University of Saskatchewan researchers, demonstrated that extensive use of liquid carbofuran to control grasshoppers was a serious contributing factor in the decline of the endangered Burrowing Owl.[40]

Keith Marshall's effectiveness at securing funding and support was evident not only in a revitalization and expansion at the National Wildlife Research Centre but also in the designation of CWS staff in every region to be the "eyes and ears" of the toxics group.[41] Collectively, they formed a national network of wildlife toxicology information gatherers that added greatly to the understanding of how wildlife can be used to monitor environmental trends. During a period when many CWS programs turned to a strongly regional focus, the collegial spirit linking biologists in the field with the specialists at the National Wildlife Research Centre sustained a strong sense of integrated national purpose and collaboration in wildlife toxicology. This spirit made it feasible, for example, for Pierre Mineau and Alain Baril, at headquarters, to launch an effective review of the impact of pesticides on wildlife in sloughs across the Prairies.

As more CWS biologists across Canada took up the study of contaminants in wildlife tissues, the demands on the analytical resources of the National Wildlife Research Centre grew in proportion. In this regard, one important area of development was the CWS Specimen Bank, which now constitutes the world's largest assemblage of wildlife specimens available for toxic chemical analysis. Chemical analysis capabilities in the early 1970s had been relatively primitive. Many compounds that would be almost commonplace in the 1980s were scarcely known to exist as environmental contaminants a decade earlier. Fortunately, CWS had started collecting and storing tissues for immediate and future analysis during the early DDT studies of the 1960s. Until the mid-1970s, most of these samples were stored, frozen, at the Ontario Research Foundation.

The Specimen Bank became a special CWS resource almost by default, when Jim Learning got word from the Ontario Research Foundation advising that the provincial facility would no longer have room to keep the growing national collection of samples, which included everything from the eggs of gulls to the livers of Polar Bears. For a time, the irreplaceable specimens were moved to a public cold storage facility; when local health officials objected, however, it became necessary to find a permanent home. In the spring of 1979, David Peakall appointed a tissue bank working group to find a long-term solution. Their plan called for walk-in freezers at the National Wildlife Research Centre to hold the collection, appropriate standards for gathering and documenting future specimens, and integration of the Specimen Bank system for cataloguing and data retrieval with the computerized database that served the National Registry of Toxic Chemical Residues.[42] The plan was implemented, and the collection has since grown to include more than 55 000 specimens and more than 400 000 subsamples.[43]

A good example of the bank's value followed the discovery, in the early 1980s, of TCDD ("dioxin," as it is commonly known) in Lake Ontario fish. In response, Norstrom and Hallett initiated a survey of TCDD in Herring Gull eggs from the specimen bank. It was quickly discovered that the TCDD problem was unique to Lake Ontario, and that



Mary Simon injects a sample into the National Wildlife Research Centre's mass spectrometer for ultra trace analysis of organic contaminants in this 1989 photograph (Photo credit: J. Foley).

concentrations of the substance in samples from the early 1970s were well above those that would have killed chicken embryos. Subsequently, Herring Gull eggs from the Specimen Bank have been reanalyzed for the myriad of other chemicals now known to be present in Lake Ontario. These studies showed that the compound that was most closely correlated with reproductive failures in the mid-1970s was hexachlorobenzene. However, TCDD and PCBs may also have contributed to toxic effects in the gulls. Concentrations of PCBs were sometimes found to be nearly 0.1% in the fat of Herring Gull eggs collected during the early 1970s.[44]

As important as it is to know the level of a pollutant present, it is even more important to know what the pollutant is doing to the environment. This concept led to the establishment, in the late 1980s, of a biomarker laboratory. Under Glen Fox and Suzanne Trudeau, the laboratory developed a battery of biochemical indicators to study how contaminants were affecting the health of wildlife. These techniques are widely used by CWS field biologists to track the effects of toxic substances on reproductive, immune, and endocrine functions in various species.

As research capabilities and needs evolved through the 1980s, attention turned not only to other toxic contaminants, but also to other areas besides the Great Lakes. The public attention that surrounded the discovery of TCDD in Lake Ontario had led to the acquisition of a new mass spectrometer at the National Wildlife Research Centre. Having this equipment in place enabled the toxic chemicals specialists to go back and reanalyze tissue samples from the Specimen Bank from other areas. Among the anomalies uncovered by this process was an unexpectedly high level of dioxin contamination in Great Blue Heron eggs collected from a colony on the campus of the University of British Columbia.

What followed had many of the elements of a good detective story. Because it involved not only the headquarters toxics group but also P. E. (Phil) Whitehead and Rob Butler of the Pacific and Yukon Region and, later, John E. Elliott, who transferred from the National Wildlife Research Centre to Vancouver, it also serves as a good example of regional/headquarters collaboration. The first step was to undertake heron surveys at other sites in British Columbia. It soon became clear that birds in a number of colonies were accumulating large quantities of dioxin. An even more extensive study led to the conclusion that herons were ingesting the chemical while feeding near the outlets of bleached kraft pulp mills.[45]

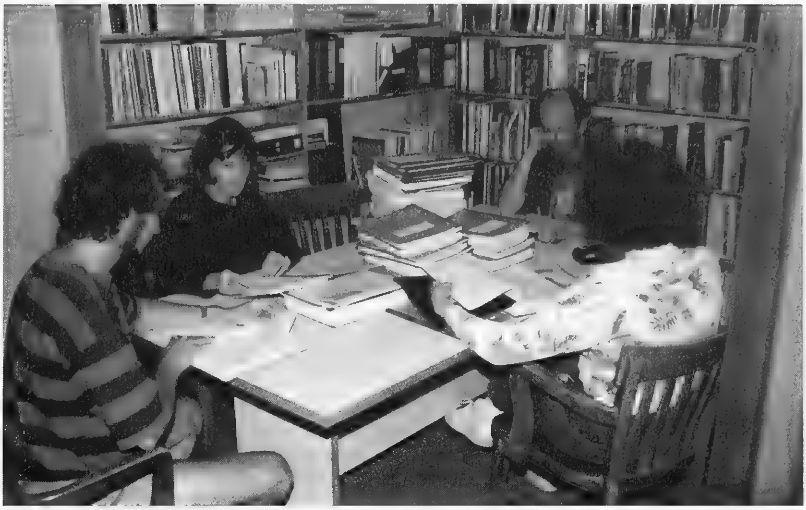
The close correlation between high dioxin levels and proximity to pulp mills pointed to the probable source of the contaminants. Not surprisingly, the pulp and paper companies resisted this conclusion, at least until their own research indicated that their use of wood chips contaminated with chlorophenol was causing the formation of dioxins in the pulping process. Faced with this evidence, they put a stop to the practice. Continued biomonitoring of the heron colonies and a general improvement of effluent treatment by the mills enabled CWS to document some rather dramatic declines in dioxins as a consequence.[46] Rob Butler's ecological work on this project led to publication of a best-selling book,[47] while Ross Norstrom had the satisfaction seeing his work on bioaccumulation of toxics applied to the identification and resolution of a specific problem.[48]

Issues of the 1990s

Success often breeds success. The work with herons established CWS as an important centre for dioxin research throughout the 1980s and 1990s. The program matured and acquired an international reputation for excellence and diversity. As a research scientist, for example, Ross Norstrom has focused in recent years on the presence of contaminant residues in Polar Bears (see Chapter 4). This area of study, first initiated by Gerry Bowes in the 1970s,[49] represents an important contribution to the Canadian Arctic Monitoring Assessment Program, a circumpolar venture involving governments, native communities, and universities. Doctoral students under Norstrom's supervision are working on bioaccumulation modelling, the effect of PCB metabolites in Polar Bears,[50] and the ability of toxic materials to enhance or suppress immune responses.

Tracking the dispersal of global contaminants can have life and death significance in areas of Canada where many of the human residents depend on wild food for their survival. If the flesh of Polar Bears, seals, Caribou, or Muskoxen is contaminated, it can pose a variety of health hazards to humans who ingest it. This problem has been addressed by Birgit M. Braune and others at the National Wildlife Research Centre. They have by no means limited their investigations to dwellers or food species of the Arctic. An extensive review and analysis of data on game birds in many parts of the country has revealed concentrations of chemical residues that, in some cases, justify concern for the health of the birds and of their consumers.[51]

The threat to human health from country food constitutes a link between Braune's studies in the 1990s and many other CWS investigations of toxics in wildlife over the years. Several enquiries under the Great Lakes Program pointed to the potential for disruption of the human endocrine system as a result of regular consumption of contaminated fish. This finding, in turn, echoed the health hazards revealed by the work of Fimreite, Vermeer, Barr, and others who demonstrated the spread of mercury in aquatic ecosystems as far back as the 1960s.



Members of the pesticide unit Pierre Mineau (*l.*), Céline Boutin, Alain Baril, and an associate evaluate company data for pesticide registration (Photo credit: CWS).

Indeed, mercury resurfaced during the 1990s as an ongoing source of concern, both as a direct byproduct of human activity and in areas where the toxic metal was released into lakes and streams from soils and exposed rock. In the Quebec Region, the creation of large reservoirs behind the dams of the James Bay hydroelectric power development provided an unusual opportunity for research. Jean-Luc DesGranges and Jean Rodrigue analyzed blood and feather samples from Ospreys to determine whether these fish-eating top predators were suffering adverse effects from mercury released from organic debris on the flooded lands.[52]

In another study, the Common Loon was selected by an international research team of Canadian and American biologists as an ideal indicator species for study. Starting in 1991, samples of blood and feathers were taken from loons in five regions of North America: Alaska, the northwestern United States, the Great Lakes, New England, and the Maritime provinces.[53] The principal CWS participants in this project were Neil Burgess in the field and Tony Scheuhammer at the National Wildlife Research Centre.

Tony Scheuhammer and Sean Kennedy joined the research team at the National Wildlife Research Centre in the early 1990s. In addition to his work with mercury in loons, Scheuhammer became a major contributor to the broad discussion of heavy metals in the environment, and especially the problem of lead poisoning in birds as a result of the ingestion of spent shot. Given the CWS mandate to conserve and protect migratory game birds, this was a particularly important and sensitive topic. As early as the 1970s, Nolan Perret had conducted laboratory and field experiments in an effort to find an acceptable substitute for lead in shotgun ammunition. Because hunters preferred the superior carrying and impact qualities of lead shot, however, there had been widespread reluctance to address the question of whether the pellets that ducks and geese swallowed while feeding in Canadian marshes were responsible for significant contamination and loss of migratory waterfowl. The more popular view among hunters and regulators alike was that this problem was limited to wintering sites in the southern United States.

To test this hypothesis, Scheuhammer analyzed lead in bones from wing samples submitted in annual Canadian hunter surveys. Selecting wings from first-year birds, in order to eliminate the possibility of imported contamination, he was able to map elevated concentrations of lead in waterfowl across Canada.[54] This proved to be one of the key findings that led to the phasing out of lead shot for hunting migratory game birds.

Much of Sean Kennedy's work, meanwhile, focused on the establishment of ecological toxic equivalency factors to determine the relative sensitivity of different species to the same toxins. CWS interest in this area of research stemmed initially from Glen Fox's interest in the varying cellular and biochemical effects of toxic substances on organisms and from Norstrom's Polar Bear work. In a related vein, CWS set out to test the widely held assumption that sensitivity to contaminants increased with size. Laboratory testing had repeatedly shown that, among mammals, it took a relatively larger dose per unit of weight to drug a rat than a human. Toxicologists had assumed for a long time that the same pattern of response applied to birds as well. When CWS toxicologists actually reviewed data on this topic for the first time, however, they were surprised to find that the reverse was true. Gram for gram, a 7-gram Golden-crowned Kinglet turned out to be far more sensitive than a 1000-gram Mallard, which happens to be one of the designated test species for pesticide toxicity.

A recent instance of pesticide damage to birds, and one that illustrates vividly the global nature of environmental hazards, involved the CWS Pesticides Section in questions of international trade and the agricultural policies of a foreign power — Argentina. During the 1980s, a large area of land at the junction of the provinces of La Pampa, Buenos Aires, and Cordoba was converted from natural prairie to intensive cultivation of grains, alfalfa, and sunflowers, crops that are vulnerable to attack by grasshoppers. The preferred agent for grasshopper control in this setting was a product called monocrotophos. Grasshoppers are a preferred prey species for Swainson's Hawks. On a visit to the area in 1994–1995, Brian Woodbridge, an endangered species specialist with the United States Forest Service, discovered that the raptors were homing in on heavy grasshopper infestations and consuming lethal doses of the pesticide.[55] When he returned to the area in 1995–1996, he calculated that season's toll at no fewer than 20 000 hawks.

With a North American breeding population estimated at 200 000 to 400 000 birds, the Swainson's Hawk was still relatively abundant. Nevertheless, an annual loss of at least 5% to 10% of those birds annually to incidental pesticide poisoning, when added to natural mortality, could add up to a severe stress over a few years. As the senior pesticide researcher at CWS, Mineau travelled to Argentina to encourage remedial action.

> I think it helped. We certainly got restrictions on their use of monocrotophos and got the company [Ciba-Geigy] committed to taking action. Later in the season, an American pressure group called the American Bird Conservancy [ABC], which is the U.S. affiliate of Bird Life [formerly the International Council for Bird Preservation], started pressuring them to pull their product from the area where the hawks were wintering. That's gone a step further now. ABC has arranged for a worldwide review of monocrotophos. The product has been approved for use in 65 countries, mostly in the developing world, and it's reportedly the second-largest selling insecticide in the world.[56]

When CWS first created a pesticides and toxics unit in the 1960s, Tony Keith had predicted that its success would depend on a combination of solid scientific evidence and constructive lobbying. Having a dual mandate worked very much to the advantage of CWS in this regard. On the one hand, it was a recognized participant in the registration process. On the other hand, its duties under the Migratory Birds Convention Act permitted it to engage in pesticide-related projects that fell well beyond a purely regulatory and administrative function.

In 1993, that role changed. A decision was made to establish a stand-alone agency outside of Agriculture Canada to review and approve pesticides. The Pesticide Management Regulatory Agency, comprising most of the federal employees and resources dedicated to pesticide assessment, now operates under the aegis of Health Canada. CWS elected to retain its own, separate pesticide unit, largely because the new agency has no mandate to conduct any research, whether before or following the registration of a chemical. The risk inherent in this decision is that it removes the Wildlife Service from direct participation in the regulatory process and immediate access to the information it generates. The advantage is that there is still one group of pesticide specialists in Canada that is free to operate with the flexibility and perspective of the wildlife mandate.

This degree of independence enables CWS to sustain a position at the leading edge of the wildlife toxicology field, from which it is possible to address the ever-widening circle of issues inherent in the concept of global biodiversity at the end of the 1990s. The work of CWS researchers such as Christine Bishop, Louise Champoux, Jean Rodrigue, Bruce Pauli, and others with Snapping Turtles, frogs, and Mudpuppies[57] indicates how far the agency has moved from the days, half a century ago, when its mandate was primarily defined by the Migratory Birds Convention Act.

Notes

1. Quoted in H. Hurtig, "Personal responsibility in association with pesticide use" in *1961 Wildlife Management Papers* (Ottawa: Canadian Wildlife Service, 1961), page 40.
2. Quoted in Hurtig, "Personal responsibility," pages 40–41. (See note 1)
3. D. Janzen, Remarks in *Minutes of the 25th Federal–Provincial Wildlife Conference*, 15–16 June 1961, Ottawa (Ottawa: Canadian Wildlife Service, 1961), page 28.
4. Quoted in Hurtig, "Personal responsibility," page 41. (See note 1)
5. Pierre Mineau, personal communication, November 1997.
6. Victor E. F. Solman, "Biocides and wildlife" in *Minutes and Papers of the 27th Federal–Provincial Wildlife Conference*, April 1963, Ottawa (Ottawa: Canadian Wildlife Service, 1963), page 47.
7. Recommendation Number 2 in *Proceedings and Papers of the 28th Federal–Provincial Wildlife*

Conference, 18–19 June 1964, Charlottetown, Prince Edward Island (Ottawa: Canadian Wildlife Service, 1964).

8. J. A. Keith, personal communication, interviewed at Ottawa, 6 December 1996.
9. Office of the Prime Minister, "Statement by the Prime Minister on DDT and other organochlorine pesticides," Press release, House of Commons, 3 November 1969.
10. D. R. Macdonald, "Aerial spraying against the spruce budworm in New Brunswick, 1960 to 1963," *Canada Department of Forestry Bi-monthly Progress Report* 20(1):1–2 (1964).
11. C. David Fowle, *A Preliminary Report on the Effects of Phosphamidon on Bird Populations in Central New Brunswick* (Ottawa: Canadian Wildlife Service Occasional Paper Number 7, 1965).
12. C. David Fowle, *Effects of Phosphamidon on Forest Birds in New Brunswick* (Canadian Wildlife Service Report Series, Number 16, 1972).
13. Peter Pearce, personal communication, June 1997.
14. P. A. Pearce, D. B. Peakall, and A. J. Erskine, *Impact on Forest Birds of the 1975 Spruce Budworm Spray Operation in New Brunswick* (Ottawa: Canadian Wildlife Service Progress Notes Number 62, 1976). In 1970, Anne Rick and Iola Price monitored amphibians in an area of Fundy National Park sprayed with fenitrothion, finding no unusual effects. P. A. Pearce and I. M. Price, "Effects in amphibians" in M. L. Prebble (editor), *Aerial Control of Forest Insects in Canada* (Ottawa: Environment Canada, 1975), pages 301–305.
15. D. Busby, personal communication, interviewed at Sackville, New Brunswick, May 1992.
16. D. G. Busby, L. M. White, P. A. Pearce, and P. Mineau, "Fenitrothion effects on forest songbirds: a critical new look" in W. R. Ernst, P. A. Pearce, and T. L. Pollock (editors), *Environmental Effects of Fenitrothion Use in Forestry: Impacts on Insect Pollinators, Songbirds, and Aquatic Organisms* (Environment Canada, Conservation and Protection Branch, Atlantic Region, 1989), pages 47–48.
17. Busby et al., "Fenitrothion effects," page 88. (See note 16)
18. W. L. Fairchild, W. R. Ernst, and V. N. Mallet, "Fenitrothion effects on aquatic organisms" in W. R. Ernst, P. A. Pearce, and T. L. Pollock (editors), *Environmental Effects of Fenitrothion Use in Forestry: Impacts on Insect Pollinators, Songbirds, and Aquatic Organisms* (Environment Canada, Conservation and Protection Branch, Atlantic Region, 1989), page 119.
19. P. G. Kevan and R. C. Plowright, "Fenitrothion and insect pollinators" in W. R. Ernst, P. A. Pearce and T. L. Pollock (editors), *Environmental Effects of Fenitrothion Use in Forestry: Impacts on Insect Pollinators, Songbirds, and Aquatic Organisms* (Environment Canada, Conservation and Protection Branch, Atlantic Region, 1989), pages 23–24.
20. Fairchild et al., "Fenitrothion effects," page 120. (See note 18)
21. W. R. Ernst, P. A. Pearce, and T. L. Pollock (editors), *Environmental Effects of Fenitrothion Use in Forestry: Impacts on Insect Pollinators, Songbirds, and Aquatic Organisms* (Environment Canada, Conservation and Protection Branch, Atlantic Region, 1989).
22. Richard W. Fyfe, J. Campbell, B. Hayson, and K. Hodson, "Regional population declines and organochlorine insecticides in Canadian Prairie Falcons," *The Canadian Field-Naturalist* 83: 191–200 (1969).
23. N. Fimreite, R. W. Fyfe, and J. A. Keith, "Mercury contamination of Canadian prairie seed eaters and their avian predators," *The Canadian Field-Naturalist* 84(3): 269–276 (1970).
24. J. F. Barr, *Population Dynamics of the Common Loon* (Gavia immer) *Associated with Mercury-contaminated Waters in Northwestern Ontario* (Ottawa: Canadian Wildlife Service Occasional Paper Number 56, 1986).
25. Ross Norstrom, personal communication, interviewed at Hull, Quebec, 5 December 1996.
26. M. Gilbertson, "Pollutants in breeding Herring Gulls in the lower Great Lakes," *The Canadian Field-Naturalist* 88: 273–280 (1974).
27. R. J. Allan, A. J. Ball, V. W. Cairns, G. A. Fox, A. P. Gilman, D. B. Peakall, D. A. Piekarz, J. C. Van Oostdam, D. C. Villeneuve, and D. T. Williams, *Toxic Chemicals in the Great Lakes and Associated Effects: Volume 1, Contaminant Levels and Trends* (Ottawa: Environment Canada, 1991).
28. C. V. Weseloh, P. Mineau, and D. J. Hallett, "Organochlorine contaminants and trends in reproduction in Great Lakes Herring Gulls, 1974–78," *Transactions of the North American Wildlife and Natural Resources Conference* 44: 543–557 (1979).
29. Weseloh et al., "Organochlorine contaminants." (See note 28)
30. I. M. Price and D. V. Weseloh, "Increased numbers and productivity of double-crested cormorants, *Phalacrocorax auritus*, on Lake Ontario," *The Canadian Field-Naturalist* 100: 474–482 (1986).
31. D. V. Weseloh, S. M. Teeple, and M. Gilbertson, "Double-crested cormorants of the Great Lakes: egg-laying parameters, reproductive failure, and contaminant residues in eggs, Lake Huron, 1972–1973," *Canadian Journal of Zoology* 61: 427–463 (1983). Great Lakes seabird populations were not the only ones to show signs of reproductive failure linked to DDT. In the Gulf of St. Lawrence, a similar relationship was found in the Northern Gannet colony at Bonaventure Island. cf. G. Chapdelaine, P. Laporte, and D. N. Nettleship, "Population, productivity and DDT contamination trends of Northern Gannets (*Sula bassanus*) at Bonaventure Island, Quebec, 1967–1984," *Canadian Journal of Zoology* 65: 2922–2926 (1987).
32. G. A. Fox, B. Collins, E. Hayakawa, D. V. Weseloh, J. P. Ludwig, T. J. Kubiak, and T. C. Erdman, "Reproductive outcomes in colonial fish-eating birds: a biomarker for developmental toxicants in Great Lakes food chains. II. Spatial variation in the occurrence and prevalence of bill defects in young double-crested cormorants in the Great Lakes, 1979–1987," *Journal of Great Lakes Research* 17(2): 158–167 (1991).
33. R. G. Butler, A. Harfenist, F. A. Leighton, and D. B. Peakall, "Impact of sublethal oil and emulsion exposure on the reproductive success of Leach's storm-petrels: short and long-term effects," *Journal of Applied Ecology* 25: 125–143 (1988).
34. D. K. McNicol, B. E. Bendell, and R. K. Ross, *Studies of the Effects of Acidification on Aquatic Wildlife in*

Canada: Waterfowl and Trophic Relationships in Small Lakes in Northern Ontario (Ottawa: Canadian Wildlife Service Occasional Paper Number 62, 1987), page 14.
35. Joseph J. Kerekes, *Long Range Transport of Air Pollutants — A Research Proposal* (Ottawa: Environment Canada, Canadian Wildlife Service, 1977; reprinted December 1994).
36. McNicol et al., "Studies of the effects of acidification." (See note 34)
37. Jean-Luc DesGranges, *Studies of the Effects of Acidification on Aquatic Wildlife in Canada: Lacustrine Birds and their Habitats in Quebec* (Ottawa: Canadian Wildlife Service Occasional Paper Number 67, 1989).
38. P. J. Blancher, D. K. McNicol, R. K. Ross, C. H. R. Wedeles, and P. Morrison, "Towards a model of acidification effects on waterfowl in eastern Canada," *Environmental Pollution* 78: 57–63 (1992).
39. Pierre Mineau, personal communication, interviewed at Hull, Quebec, 5 December 1996.
40. Glen A. Fox, Pierre Mineau, Brian Collins, and Paul C. James, *The Impact of the Insecticide Carbofuran (Furadan 480F) on the Burrowing Owl in Canada* (Ottawa: Canadian Wildlife Service Technical Report Series, Number 72, 1989).
41. Each region identified dedicated pesticide and contaminant specialists: John Elliott and Phil Whitehead in Pacific and Yukon; Doug Forsyth and Mark Wayland in Western and Northern; Chip Weseloh and Christine Bishop in Ontario; Louise Champoux and Jean Rodrigue in Quebec; Neil Burgess in Atlantic.
42. R. J. Norstrom, D. J. Hallett, A. P. Gilman, and W. J. Learning, *Report of the NWRC Tissue Bank Workgroup*, internal CWS memorandum and report to Chief, Wildlife Toxicology Division, 27 November 1979 (Hull, Quebec: Canadian Wildlife Service, National Wildlife Research Centre, Files of Director's Office, 1979).
43. B. J. Wakeford and M. T. Kassera, "The relationship between the Canadian Wildlife Service specimen bank and the wildlife toxicology program: the effect on specimen collection," *Chemosphere* 34(9/10): 1933–1938 (1997).
44. Ross Norstrom, personal communication, November 1997.
45. J.E. Elliott, R.W. Butler, R.J. Norstrom, and P.E. Whitehead, *Levels of Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans in Eggs of Great Blue Herons* (Ardea herodias) *in British Columbia, 1983–87: Possible Impacts on Reproductive Success* (Ottawa: Canadian Wildlife Service Progress Notes Number 176, 1988).
46. J. E. Elliott, R. W. Butler, R. J. Norstrom, and P. E. Whitehead, "Environmental contaminants and reproductive success of Great Blue Herons (*Ardea herodias*) in British Columbia 1986–87," *Environmental Pollution* 59: 91–114 (1989).
47. R. W. Butler, *The Great Blue Heron* (Vancouver: University of British Columbia Press, 1997).
48. Norstrom, personal communication. (See note 25)
49. C. W. Bowes and C. J. Jonkel, "Presence and distribution of polychlorinated biphenyls (PCBs) in arctic and subarctic marine food chains," *Journal of the Fisheries Research Board of Canada* 32: 2111–2123 (1975).
50. Robert J. Letcher, *The Ecological and Analytical Chemistry of Chlorinated Hydrocarbon Contaminants and Methyl-sulfonyl-containing Metabolites of PCBs and 4,4-DDE in the Polar Bear (*Ursus maritimus*)* (Ottawa: Carleton University, 1996).
51. Birgit M. Braune, Michael P. Wong, Jean-Claude Belles-Isles, and W. Keith Marshall, *Chemical Residues in Canadian Game Birds* (Ottawa: Canadian Wildlife Service Technical Report Series, Number 124, 1991).
52. J. L. DesGranges, J. Rodrigue, and B. Tardif, "Exposition au mercure chez de jeunes balbuzards au nid dans les territoires de la Baie-James et de la Baie d'Hudson" in *Comptes rendus du vingtième atelier sur la toxicité aquatique, Québec. Rapport technique canadien des sciences halieutiques et aquatiques* 1989: 20–21 (1994).
53. David C. Evers, Joseph D. Kaplan, Michael W. Meyer, Peter S. Reaman, W. Emmett Braselton, Andrew Major, Neil Burgess, and Anton M. Scheuhammer, "Geographic trend in mercury measured in common loon feathers and blood," *Environmental Toxicology and Chemistry* 17(2): 173–183 (1997).
54. A. M. Scheuhammer and S. L. Norris, *A Review of the Environmental Impacts of Lead Shotshell Ammunition and Lead Fishing Weights in Canada* (Ottawa: Canadian Wildlife Service Occasional Paper Number 88, 1995).
55. P. Mineau, *An Assessment of the Factors which Contributed to the Recent Pesticide Kills of Swainson's Hawks in the Argentine Pampas and Recommendations to Prevent a Re-occurrence* (Ottawa: Canadian Wildlife Service, National Wildlife Research Centre, internal report, 1996).
56. Mineau, personal communication. (See note 39)
57. Christine A. Bishop and Karen E. Pettit, *Declines in Canadian Amphibian Populations: Designing a National Monitoring Strategy* (Ottawa: Canadian Wildlife Service Occasional Paper Number 76, 1992).

1982–1987: Building Partnerships

When he assumed the leadership of CWS in 1981, Bert Tétrault was the first head who had not risen to the job through the ranks of the federal agency. Indeed, his background as a fisheries biologist with the Quebec government may have made him more understanding of the provincial viewpoint in wildlife policy issues. Characterizing himself as a "new broom," he announced the immediate launching of an extensive internal review of programs and activities, aimed at ensuring that every dollar of a constrained budget was being exchanged for the best possible value.[1]

At a farewell luncheon held in honour of Joe Bryant on the occasion of his retirement in 1983, the guest of honour (*l.*) listened intently while long-time colleague Hugh Boyd emphasized a point (Photo credit: J. Foley).

The review process was put in the hands of a working group headed by Quebec Regional Director Pierre Desmeules and including Jim Foley and Gaston Moisan. By the spring of 1983, they had come back with a draft conceptual plan for federal wildlife management in which was proposed a major reassessment of the respective roles and responsibilities for wildlife of the federal and other levels of government. Closer federal–provincial cooperation was to be the order of the day, based on a clarification of the economic and ecological values of migratory birds. Some federal responsibilities might be delegated to the provinces, on request, and a cooperative effort would be initiated to develop national principles, standards, and management criteria.

The concept of cooperative management initiatives received an important boost at the 48th Federal–Provincial Wildlife Conference, held in Timmins, Ontario, in June 1984. The theme of the gathering was "Teamwork in Wildlife Management," and Tétrault was pleased to be able to point to a shining example of what this meant when he announced that a new organization, Wildlife Habitat Canada, had received its Charter the preceding February. It emerged as a spinoff from the continuing efforts of Jim Patterson, George Finney, and others to negotiate a continental waterfowl management plan (see Chapter 6).

This new style of multistakeholder foundation was governed by a board of directors that included federal and provincial officials as well as representatives from nongovernment organizations and private industry. Wildlife Habitat Canada received $3 million in federal startup and administrative grants over its first two years. By its third year, sustaining revenues were to come largely from the sale of a special Wildlife Habitat Conservation Stamp that was introduced to accompany the migratory game bird hunting permit.

Other issues that preoccupied CWS and its provincial counterparts during the early 1980s also tended to illustrate the need for constructive collaboration between governments. The search for offshore oil and gas in the high Arctic and off Newfoundland, for example, had direct and potentially dreadful implications for coastal habitats and marine habitats within the territorial waters of both Canada and the United States. Other transborder concerns of CWS in the north included participating in three Caribou management boards (see Chapter 4) and, in collaboration with Parks Canada, developing an action plan for the protection of natural areas north of 60°N. Work on endangered species was meeting with success, notably in the development and implementation of cooperative recovery plans for the Whooping Crane and the Peregrine Falcon. On the international scene, the CWS Latin American Program was returning useful dividends in terms of wetland classification work, toxic chemicals research, and shorebird migration. It was also encouraging the unprecedented development of an effective network of conservation biologists in the western hemisphere.

Despite the less affluent times, it appeared that the CWS agenda was unfolding in a steady and constructive manner. And then, in presenting the 1985 spending estimates, Environment Minister Suzanne Blais-Grenier unleashed a tremor that shook the entire organization (see Chapter 7). Bert Tétrault, looking back eight months after the event, recalled:

> CWS was amputated of 22% of its resources on 9 November 1984. It was a shock for all of us, and since that time we have had to do a lot of rethinking with regard to our mandate. As a result, we are undergoing a reorganization and realignment of program within CWS.[2]

Environment Canada's new perspective on the management of wildlife in Canada appeared to reflect a narrow view of the Canada Wildlife Act on the part of the Conservative government of Prime Minister Brian Mulroney. Interpretive programs, despite being specifically authorized under the Act, were eliminated on the grounds that they were educational and hence fell under provincial jurisdiction. Research, too, was cut unless it was related to specific departmental responsibilities for migratory birds, threatened and endangered species, wildlife in national parks, or national and international agreements. The loss of staff virtually gutted the Research and Interpretation Branch and precipitated a radical reshuffling of programs and priorities in an effort to save irreplaceable personnel and activities within programs that had escaped the fiscal axe.

The cutbacks, announced in November, were implemented at the outset of the new fiscal year in April 1985. Of this troubled moment it is probably no exaggeration to say that the identity and mission of CWS were saved by the successful finalization of NAWMP (see Chapter 6). The joint Canada–USA commitment to a continental strategy for protection and stewardship of wetland habitat was signed in Washington in May 1985 by the newly appointed Environment Minister, Tom Macmillan, and the United States Secretary of the Interior. By setting specific, large-scale targets for securement, enhancement, and waterfowl population growth, and by assuring multiyear financial backing for the programs needed to achieve them, the agreement helped restore a sense of purpose to a Wildlife Service that had suffered a crushing blow to its collective momentum and morale.

NAWMP established a framework for constructive action at a time when it was sorely needed. Through its chosen strategy of broadly based regional joint venture initiatives, it invited widespread partnerships, collaboration, and networking. Although its focus was on increased waterfowl production, it clearly favoured an ecological approach to the achievement of that goal and recognized the conservation and enhancement of biodiversity as both a concomitant benefit and a valid indicator of success. There were pragmatic advantages to the agreement, too. Because most North American waterfowl nest in Canada, implementation of the plan channelled millions of American dollars into Canadian habitat conservation. As a result, CWS was able to reassign a number of biologists and technicians whose previous jobs had been cut to work on waterfowl projects funded under NAWMP.

In 1986, Bert Tétrault left CWS to embark on a senior executive training plan at the National Defence College in Kingston, Ontario. H. A. (Tony) Clarke, his successor as Director General, found himself at the helm of a much-transformed Wildlife Service. Presumably in order to infuse the larger Environment Canada organization with greater unity of purpose and identity, a major reorganization of the department had greatly diminished the cohesiveness of CWS as an integrated national agency. Starting in the spring of 1986, three arms of Environment Canada — CWS, Inland Waters, and Environmental Protection — were merged at the operational level into a single Conservation and Protection Service. Each Regional Director of the Wildlife Service no longer reported to the Director General of CWS in Ottawa, but to a Regional Director General of Conservation and Protection. As Director General of CWS, therefore, Clarke found himself and his headquarters units occupying a largely functional role, promoting and coordinating national policies and programs, administering international commitments such as CITES, and providing central scientific services to regional activities via the National Wildlife Research Centre.

Although both headquarters and regional offices still bore the CWS label and communicated on a daily basis concerning programs and projects, the fact remained that regional activities were now authorized and evaluated in the context of a regional Conservation and Protection agenda. Despite this shift, Clarke and the headquarters and regional directors continued to function effectively as a CWS Executive Committee, ensuring a national coherence to wildlife programs that was not necessarily as easy to achieve elsewhere in the department under the new structure.

CWS experienced profound challenges and changes from 1984 to 1986. Nevertheless, the spirit of resilience and dedication that had always characterized the agency at its best did not fail it now. By the beginning of 1987, a new momentum was building, not only around NAWMP ventures but in a variety of other exciting national and international partnerships. A national "Wildlife Colloquium" in May 1986 had reaffirmed the basic commitment to federal–provincial cooperation on wildlife conservation and called for an updating of the "Guidelines for Wildlife Policy in Canada."[3]

Other opportunities for creative collaboration were also emerging. The establishment of the Wildlife Toxicology Fund, in alliance with the World Wildlife Fund (Canada), enabled David Peakall at the National Wildlife Research Centre to extend the positive influence of the wildlife toxicology program beyond the limits of CWS projects. The CWS-inspired Wildlife Habitat Canada foundation reached an important milestone on the road to financial self-sufficiency with the launching of the first Wildlife Habitat Conservation Stamp, designed by world-renowned Canadian wildlife artist Robert Bateman. The CWS Latin American Program was flourishing. And CWS opinion surveys demonstrated higher levels of interest and support for the conservation and protection of wildlife than ever before.[4]

Notes

1. B. Tétrault, "Update report on the Canadian Wildlife Service" in *Transactions of the 46th Federal–Provincial Wildlife Conference*, 1–4 June 1982, Whitehorse (Ottawa: Canadian Wildlife Service, 1982), page 30.
2. B. Tétrault, "Report on the Canadian Wildlife Service" in *Transactions of the 49th Federal–Provincial Wildlife Conference*, 25–28 June 1985, Halifax (Ottawa: Canadian Wildlife Service, 1985), page 29.
3. Canadian Wildlife Service, *A Colloquium on Wildlife Conservation in Canada: Proceedings* (Ottawa: Canadian Wildlife Service, 1986).
4. F. L. Filion, E. DuWors, A. Jacquemot, P. Bouchard, P. Boxall, P. A. Gray, and R. Reid, *The Importance of Wildlife to Canadians in 1987: Highlights of a National Survey* (Ottawa: Minister of Supply and Services Canada, 1989).

CHAPTER 9. Endangered Species

Trumpeter Swan

"Well, Mackay," said Harrison Lewis, "your first job will be to find out how many Trumpeter Swans there are in Canada and where they are located."

It was the spring of 1950, and the Chief of the Dominion Wildlife Service was taking advantage of a trip to Vancouver to size up one of his newest recruits, Ron Mackay, a veteran of the Royal Canadian Navy. Following his discharge at the end of the Second World War, Mackay had seized the opportunity offered to returning servicemen to pursue a university education and had graduated with a degree in wildlife biology from the University of British Columbia. Aided by the good offices of his professor, Ian McTaggart-Cowan, he had found summer employment on waterfowl surveys directed by Jim Munro, Dominion Wildlife Officer for British Columbia. When Munro had retired, in October 1949, Mackay had applied for the vacated position and won it.

The Trumpeter Swan assignment made Mackay a pioneer in CWS work with species at risk. Only three years before, Taverner had described the largest waterfowl in North America as "approaching extinction."[1] By 1950, the swans' only nesting location in Canada was at Valhalla Lake, near Grande Prairie, Alberta. Mackay consulted with David Munro, his CWS colleague in Vancouver, and with field officers of the Alberta and British Columbia game departments before setting out for Grande Prairie for his first summer of fieldwork with the giant white birds. It was the beginning of a three-year study that would evolve into a life-long interest.

From 1950 to 1952, Mackay visited the site every summer to conduct an annual census of nesting pairs and to count their eggs and record successfully fledged young. At the outset, he found a Grande Prairie population of 100 to 150 swans. Banding them was a high priority. The young cygnets could be banded on the nest, but he pursued the adults in a 14-foot canoe equipped with a two-horsepower outboard motor, scooping them up in an oversized landing net. The work was not without hazards. When he was checking nests for eggs and newly hatched young, he carried a hefty willow staff, and more than once he was forced to use it to hold an angry parent at bay while he completed his work.

The fall migratory route of the Valhalla Lake swans led them south to wintering grounds in Wyoming; each year as they took their departure, however, birds from another population that bred in Alaska were arriving at Lonesome Lake in the Bella Coola Valley of British Columbia, where they would remain until the end of March. These birds were the special passion of Ralph Edwards, an American naturalist who had made his home there since emigrating from the United States in 1912. Following the Second World War, Edwards raised concerns that there might be too little natural food in the immediate vicinity of the lake to sustain the wintering flock.

The Wildlife Service took on the responsibility of providing supplementary feed, and during the next few years that population prospered.

The success of the Lonesome Lake birds attracted wide interest and on at least one occasion put the Wildlife Service to an unexpected test, as Harrison Lewis reported:

> When the Princess Elizabeth visited Charlottetown, Prince Edward Island, in October 1951, the Hon. R.H. Winters, Minister of Resources and Development, made a presentation to Her Royal Highness of six Trumpeter Swans. The birds so presented were not in captivity or under control; they were wild and free. Mr. Winters depended upon the Canadian Wildlife Service, a part of his department, to capture them and make good his presentation.
>
> There had been no advance consultation with the Wildlife Service about the matter. While the Service assuredly appreciated their Minister's great confidence in them, they realized that they were placed in a bit of a spot. As it turned out, the royal recipient of the gift would ascend the throne and become Queen of England and of Canada before the presentation assumed substance.[2]

Meanwhile, protective measures at the Grande Prairie nesting grounds were also paying off with a steadily growing swan population. When CWS divided its national program into eastern and western administrative regions in 1962, Mackay was transferred from Vancouver to the Edmonton office as Supervisor of Operations for the Western Region. Although his workplace was now much closer to the swans, the added administrative duties cut seriously into his time for fieldwork. Eventually, the project passed to Harold Weaver, from him to Bruce Turner, and then to Len Shandruk.

During the past 30 years, the Trumpeter Swan's breeding range has expanded greatly. Captive breeding and release strategies, largely conducted by volunteer aviculturists, have resulted in successful reintroduction of the species to locations where habitat and climatic conditions are suitable for both nesting and wintering. Nesting now occurs regularly in locations ranging from the Yukon to the Cypress Hills of southwestern Saskatchewan. In the spring of 1993, a released pair of captive-bred swans even nested successfully at the Wye Marsh in central Ontario. It was the first time in more than two centuries that wild Trumpeter Swans had been hatched in Ontario.[3]

While captive breeding initiatives have met with some success, CWS efforts on behalf of the swans have focused on a different range extension strategy. For about eight years, from the late 1980s to the mid-1990s, biologist Len Shandruk directed a swan relocation project in the Western and Northern Region. Using a helicopter to capture breeding adult pairs and their cygnets at Grande Prairie during the moult, he transplanted entire family groups to selected lakes in Elk Island National Park. The first capture and release took place in 1987. By 1993, a total of 10 swan families had been moved successfully. Meanwhile, in 1989, the pace of the transfer program had been accelerated with the testing of a new technique. Nearly fledged cygnets were captured without their parents and released on Elk Island lakes in the hope that they would team up with birds already established there. This experiment, too, was a success.

In 1994, Len Shandruk was reassigned to work on the establishment of the proposed Suffield National Wildlife Area, and ongoing responsibility for the Trumpeter Swan program passed to CWS biologist Gerry Beyersbergen.

Today, their population at about 3000, Canada's Trumpeter Swans are no longer at risk of extinction. Rather, one of the greatest problems they face is the pressure they themselves are putting on their wintering habitat. Steadfastly attached to traditional locations, the majority of the birds return annually to the tristate area in and around Yellowstone National Park in such numbers that they trample and overgraze the available range. CWS biologists have been collaborating with their counterparts in the United States in encouraging the swans to transfer their allegiance to alternative locations.[4] A breakthrough occurred in 1992 when three birds that had been transplanted by CWS migrated to a new wintering location in Oregon and returned to Elk Island the following spring.

Whooping Crane

Although the Trumpeter Swan was the first endangered migratory bird species to command the intervention of CWS in an organized recovery strategy, another species of large white bird would become North America's chief icon of species preservation. The Whooping Crane is one of only two crane species in North America. Its only known nesting areas lie within the boundaries of Wood Buffalo National Park. It winters on the Gulf Coast of Texas in the Aransas National Wildlife Refuge, a protected area established by the United States in 1937 for the purpose of preserving suitable habitat for the tall, handsome birds.

Whooping Cranes were never numerous. A pre-Confederation estimate put the population between 1300 and 1400 birds.[5] By 1950, a variety of causes, including illegal shooting, harsh weather, and the encroachment of dangerous obstacles such as power lines and microwave towers along the cranes' migratory flight path, had reduced them to a tiny remnant flock of 16.[6]

At the time when the Wildlife Service came into being, nothing could be done for the whoopers on their Canadian nesting grounds for the simple reason that their location was unknown. However, on 1 July 1954, mammalogist Bill Fuller sent a telegram to CWS headquarters in Ottawa. It carried exciting news. The day before, on 30 June, G. M. Wilson,

Trumpeter Swans were one of the first species at risk to attract the attention and care of the Wildlife Service. Here, biologist Ron Mackay examines an immature bird on nesting grounds near Grande Prairie, Alberta (Photo credit: CWS).

Superintendent of Forestry for Wood Buffalo National Park, and Don Landells, helicopter pilot, had spotted four Whooping Cranes. Three were adults, white with striking red caps, but one was unmistakably a juvenile in cinnamon brown plumage. The birds were in wetlands near the Sass River in the northern part of the park. Fuller himself went out the following day and confirmed that the nesting area of one of the world's rarest birds had been found.

In 1955, further investigations of the site led to observation from the air of a number of nests. Initial steps were taken, at both administrative and field levels, to develop a protective strategy for the birds. The following year, David Munro, by then Chief Ornithologist of CWS, was appointed to an International Whooping Crane Advisory Group.[7] In 1956, too, Bill Fuller transferred to Whitehorse. His successor in the CWS office at Fort Smith was Nick Novakowski. In addition to extensive duties in relation to Bison (see Chapter 4), Beaver, and boreal ecology in general, Novakowski served as guardian and godfather to the Whooping Cranes for the next nine years. He soon appreciated why it had taken so long to find their breeding grounds.

> On my first flyover I discovered that it was a strange area — almost like a waterlogged savannah. There were lots of little ponds but hardly any identifiable landmarks to orient yourself by. For the cranes it was an ideally protected summer habitat. You might occasionally see a predator in the area, like a wolf, for example, but you knew that wolf would get awfully wet before he ever got close enough to attempt to catch a bird.[8]

Novakowski's successor, Ernie Kuyt, described the protective nature of the terrain in similar terms:

> There have been a few cases where park visitors have gone off the road to try and find the nests but they have no success. Anyone who tries it is a fool. You just can't travel in that country. Even the bush pilots are amazed that I can find my way around in that area. When you do it often enough, you learn the reference points, but that's it....The parks people worry about fires, but the terrain where the cranes live is so wet that fire can't spread effectively.[9]

Each summer from 1956 to 1965, Novakowski would survey the nesting area, counting the breeding pairs, monitoring their nesting success, and recording the number of fledged young. Each fall, when the great birds took to the air for their 4000-kilometre migration, he alerted the "Whooper Network," a loose alliance of conservationists and birding enthusiasts that tracked their southward flight across Alberta, Saskatchewan, and the prairie states to Texas. His field observations, which CWS published in 1966, provided the first authoritative summary report on the nesting behaviour of the Whooping Crane.[10]

In 1966, official concern over the vulnerability of the population led to a joint agreement between CWS and the United States Fish and Wildlife Service to collaborate on a captive-breeding program to conserve the species. To accomplish this, eggs would have to be removed from nests in the wild and transported quickly and safely to the Patuxent Wildlife Research Center near Laurel, Maryland. Novakowski, the Whooping Crane specialist, had left Fort Smith on educational leave to complete his doctoral studies. Therefore, it was Ernie Kuyt, whose work till then had focused on predator–prey relationships between Wolves and Caribou, who received the following instructions:

> This memorandum is to detail Mr. Kuyt's responsibilities with regard to Operation Whooping Crane. During the period of this operation, Mr. Kuyt is to give exclusive attention to this program.
>
> On or about May 16, 1967...Mr. Kuyt will make a survey flight over the Sass River area. He should make observations that will enable the establishment of the date of egg-laying as accurately as possible. During the mid-May survey, rolls of geological orange or red marking tape should be dropped on nearby trees to facilitate re-location of the nests on the day of the pickup. For safety, the tapes should be weighted before throwing from the helicopter. It is important that the tape does not get wound around the tail rotor....
>
> Collections are to take place at the end of the third week of incubation. Collections should be made on a warm, windless day and should be completed on one day to minimize disturbance....If the weather should be inclement throughout the collection period, eggs are not to be collected and the operation will be deferred until 1968....
>
> The helicopter should not land within less than 50 yards of the nests since prop wash from the rotors may dislodge the eggs on landing or takeoff. Mr. Kuyt will leave the helicopter, remove the egg from the nest, place it in a special container, carry it back to the helicopter, and hand it to the Bureau biologist who in turn will place it in the portable incubator. The Bureau of Sport Fisheries and Wildlife personnel will be responsible for the handling of eggs after they have been placed in the incubator. Only one man will leave the aircraft.
>
> The container to be used in carrying eggs from nest to helicopter will be constructed here [i.e., in Ottawa — editor] and forwarded to Mr. Kuyt. A spare will be provided. Nest site number one (as per fig. 3, p. 7 of Dr. Novakowski's publication) will not be disturbed and will serve as a control. This is also known as "discovery nest"....
>
> If these instructions are not explicit, please phone. You will agree that no slip-up is possible....
>
> (signed)
>
> David A. Munro, Director[11]

Although he appreciated the evident concern motivating the letter's attention to detail, Kuyt knew that some of the instructions owed more to well-intentioned speculation than to first-hand knowledge. A mid-May aerial survey to establish laying dates, for example, would be useless if, as he strongly suspected, the eggs were laid at the end of April. And practical experience soon proved that it was easier and safer to transfer an egg from the nest to the helicopter in a heavy woollen sock than in the "special container" supplied from Ottawa. As Graham Cooch remarked to him, many years later, "Fortunately you paid no attention to our instructions and did it your way."[12] Working within the spirit of the project but taking the specific instructions with a grain of salt, he began an odyssey that would dominate his professional life for the next quarter century.

Nick Novakowski's research had started things in the right direction. He had observed that, as a rule, each pair of nesting cranes laid two eggs, of which only one hatched successfully.[13] Observers in Texas corroborated this finding, reporting that successfully breeding pairs arrived at Aransas with only one chick. If that second egg could be removed from the nest to be incubated, hatched, and reared elsewhere, then, at least in theory, productivity could be doubled.

Between 1967 and 1991, 128 eggs were collected in Wood Buffalo National Park and transported to Patuxent, where, it was hoped, the captive-reared birds would form the foundation stock for a breeding flock from which offspring could eventually be released into the wild. The results were discouraging. The captive birds had limited reproductive success and were susceptible to disease. By 1992, the Patuxent Wildlife Research Center breeding program had produced only 72 captive-bred birds.[14]

Another recovery strategy involved placing Whooping Crane eggs with wild Sandhill Crane foster parents in the hope of establishing a second wild population. Between 1975 and 1989, some 200 additional eggs were collected in Wood Buffalo National Park and taken to Grays Lake National Wildlife Refuge in Idaho. This program, too, met with only limited success. The fostered Whooping Cranes consistently failed to pair and produce young of their own. Kuyt and others speculate that by associating so closely with their Sandhill Crane foster parents, the young whoopers may fail to learn behaviours that are essential for triggering breeding in their own species.[15]

If the Patuxent and Grays Lake experiences were all there was to show for 30 years of joint Canada–United States intervention in Whooping Crane affairs, the value of the recovery effort would be questionable. Fortunately, a real measure of success helped to offset these disappointments. Throughout the entire period, the native wild flock was making a slow but steady recovery. To a significant degree, this would appear to have been assisted by the egg collecting initiative. At the beginning of the project, it was known that each pair of Whooping Cranes usually laid two eggs. What was not known, until data were analyzed from a number of years of collecting, was that some pairs regularly produced two viable eggs while others frequently produced one or two infertile ones. Because it was important to select viable eggs for Patuxent and Grays Lake, Ernie Kuyt soon devised a method for testing them:

> We collected the eggs late in the incubation period — about a week before they were due to hatch. At that time the embryo is large, fully formed, and moves around in the egg. You can see it by putting the egg in a bowl of

In the field, the ability to improvise has had special value. When Ernie Kuyt found that a specially designed container was impractical for safely transporting Whooping Crane eggs, he quickly hit on a substitute — a warm, dry, woollen sock, in use here at Wood Buffalo National Park on 20 May 1977 (Photo credit: E. Bizeau).

lukewarm water. As the chick moves, the centre of gravity shifts and the egg moves as well. We did that testing right at the nest so we could then leave the livelier egg and take the other one away.[16]

Being able to distinguish between viable and moribund eggs led Kuyt to ponder how that knowledge could be used to enhance nesting success in the field. Frustrated by the amount of effort that was wasted every time a pair of adult cranes spent an entire season incubating dead eggs, he hit upon a solution. If it were possible to improve the average quality of the eggs that were left in the wild, he reasoned, the result should be a measurable improvement in the level of overall breeding success. It would be a simple matter, in cases where two nonviable eggs had been laid, to remove them from the nest and replace them with one viable egg a week short of hatching.

That method has been fantastically successful. I was able to do an analysis over 4 or 5 years and found that the hatchability improved by 11% and 18%. I think that improvement in itself has been very important in the increased survival of young birds and the growth of the population numbers. At this point there are about 155 birds in the wild and we can visualize that this increase will continue. There are about 40 breeding pairs now. When I started there were about 5 or 6. It's really amazing. Where in the annals of endangered species management has there been a comparable recovery?[17]

Although Ernie Kuyt retired in the mid-1990s, the Whooping Crane program continued under the guidance of CWS biologist Brian Johns. Hopes for continued recovery of the wild flock have been bolstered in recent years by the discovery that the birds have begun to extend their nesting range southward within Wood Buffalo National Park. A 1996 census confirmed the presence of four nests south of the Northwest Territories–Alberta border.[18]

Such indicators, while encouraging, are no guarantee that the future of the Whooping Crane is assured. The Aransas Refuge lies adjacent to the busy shipping artery of the Intracoastal Waterway, where a spill from a tanker or bulk chemical carrier could have disastrous effects on the birds' sensitive winter habitat. And although the isolation of the nesting grounds provides good protection against human disturbance, significant climatic events such as prolonged drought or unseasonably cold spring weather have the potential to reduce or eliminate a year's recruitment of young cranes to the wild flock. Nevertheless, the comeback to date stands out as a remarkable example of how much can be accomplished on behalf of endangered wildlife when the efforts of dedicated individuals are backed by a sustained level of institutional and public cooperation and support that transcends geopolitical and jurisdictional boundaries. One of those dedicated individuals received fitting recognition of his contribution on 21 October 1992, when Ernie Kuyt was inducted into the Order of Canada in honour of his contribution to the recovery of the Whooping Crane.

Peregrine Falcon

The Trumpeter Swan and Whooping Crane were known to be at risk before the Wildlife Service ever became involved with them. The presence of a threat to the Peregrine Falcon, on the other hand, was discovered largely through environmental monitoring activities initiated by CWS and sister agencies in Canada and the United States.

Canada is home to three subspecies of this streamlined, powerful raptor: *anatum*, ranging across most of southern Canada; *pealei*, native to the Queen Charlotte Islands; and *tundrius*, in Arctic regions.[19] Until the late 1950s, *anatum* peregrines were widespread breeding residents across most of North America. Then, observers began to notice that traditional nest sites were no longer occupied and wondered why.

In 1963, Vic Solman delivered a paper to the 27th annual Federal–Provincial Wildlife Conference, in which he noted that unhatched Peregrine Falcon eggs in Britain were found to contain significant concentrations of DDT and other organochlorine pesticide compounds such as dieldrin and heptachlor. "Although the Canadian Wildlife Service is not yet equipped to carry out the studies in Canada necessary to gather comparable data," he wrote, "we believe it is a reasonable assumption that what is happening to wildlife in other countries as a result of chemical treatments in agricultural areas may well occur here."[20] The following year, Graham Cooch, in a further report on the implications of biocides, referred to studies in the United Kingdom that demonstrated their negative impact on the reproductive success of Golden Eagles and Peregrine Falcons.[21]

By 1966, evidence was mounting that a similar trend was occurring in North America. Speaking as a CWS biologist and a devotee of the ancient sport of falconry, Richard Fyfe reported that year, to the 30th Federal–Provincial Wildlife Conference, that there was evidence of "sharp declines [in raptor populations] in the northeastern United States and southern Canada." With particular reference to the Peregrine Falcon, he noted, "In two recent symposiums it has been suggested that the most important cause of the declines is the use of pesticides, especially the chlorinated hydrocarbons such as DDT, Aldrin and Dieldrin."[22] That the concerns he expressed were shared was evident in the adoption of the following resolution:

> Whereas the birds of prey are increasingly important because of their aesthetic and recreational values, and whereas populations of some species are or may be threatened by use of pesticides, by indiscriminate killing, and by thoughtless human interference, this conference recommends that all wildlife agencies in Canada consider the status and management of birds of prey under their jurisdiction in order to maintain the species and facilitate their national use, and to develop public appreciation of their niche in the environment.[23]

The sharp declines that Fyfe referred to amounted to a virtual extirpation of the *anatum* subspecies of peregrines in much of the United States and central and eastern Canada. Now, CWS initiated additional research to determine more accurately the extent of the problem. The recently formed Pesticides Section under Tony Keith supported Fyfe in carrying out toxic chemical monitoring and raptor studies in the prairies and the central Arctic. These and subsequent studies elsewhere in the north and in British Columbia confirmed that bioaccumulation of toxic pesticide residues and mercury was a significant problem to the health of peregrines of the *tundrius* and *pealei* subspecies as well.[24]

By the end of the decade, governments were beginning to define and implement restrictions on pesticide use. There was some doubt, however, as to how effective these measures might be. As Tony Keith wrote in 1970: "Whether these DDT reductions will come soon enough to save the collapsing continental peregrine falcon population is an open question."[25]

Participants in a Raptor Research Planning Conference held at Cornell University in November 1969 had concluded that the species should be officially designated as endangered throughout its range. As an immediate result of this meeting, Canadian and American agencies initiated a continent-wide survey of peregrine eyries, to be held every five years, beginning in 1970.[26] That year, Canadian field teams checked every known nest site from Alberta eastward, as well as conducting exploratory surveys in search of new eyries. The results were disheartening. Only one pair of peregrines of the *anatum* subspecies was confirmed as nesting successfully south of 60°N and east of the Rocky Mountains. Two active eyries were found on the Labrador coast, a location where it was thought the occupying birds were likely to be intergrades with the *tundrius* subspecies.[27] Sufficient declines were reported in the populations of *tundrius* and *pealei* birds as well that the summary report of the survey expressed concern that the Peregrine Falcon might become extinct within the decade.[28]

The 1970 survey was under way when the 34th Federal–Provincial Wildlife Conference opened in Yellowknife, and Richard Fyfe, who had been a major participant in the study, asked to present the findings to the wildlife directors. Speaking in an in camera session, he outlined the gravity of the situation and requested permission to initiate a captive breeding program and to take a sample of young for captive breeding from any remaining *anatum* nest that might be found.

The tacit approval of the directors was noted for the record in the remarks of W. G. (Glen) Smith of British Columbia:

> The alarming decline of certain raptorial birds has uncertain implications respecting the preservation of some

How to determine the viability of a Whooping Crane egg in the field? Ernie Kuyt came up with an ingenious solution. Gently place the egg in a bucket of lukewarm water to see if it moves, indicating the presence of a lively chick. Here he administers the test atop a Whooping Crane nest in Wood Buffalo National Park, on 1 August 1988 (Photo credit: Jacques Saquet).

species in a wild state. Effort should be made to develop captive populations for reintroductions.[29]

Faced with dramatic confirmation of the peregrines' plight and backed by the provincial wildlife directors, CWS acted decisively to implement the captive breeding proposal. Several young *anatum* birds were taken into captivity to serve as foundation breeding stock. The undertaking had three stated objectives:

- to maintain and preserve the *anatum* peregrine gene pools;
- to attempt to develop effective captive breeding techniques; and
- to prepare for reintroduction of birds of the *anatum* subspecies to its former range.

Having initiated the concept and the project, Richard Fyfe was assigned to coordinate the task. Not only did he have a long-standing interest in birds of prey, but he had already bred falcons successfully in captivity at his home in Alberta.[30] For the next 15 years, this work would be his all-consuming passion. In an interview in December 1996, he recalled the early days of the project:

We had to begin by acquiring breeding stock. The last pair of wild birds in the Prairies were nesting down on the Bow River. In 1971 we deliberately took the first clutch of eggs to force the pair to lay a second clutch. Three eggs were collected and taken to my home where they were put under a pair of brooding peregrines in my barn. As it turned out, not only did we succeed in raising two chicks, but the adult birds renested and raised another three on their own. Most of our stock, however, were young taken from nests along the Mackenzie River. We took them before they were fledged, at about three weeks of age, and always made sure that we weren't stripping the nest of all its young. We ended up the first year with about a dozen peregrines. Eventually we would have in the neighbourhood of 30 pairs — all of pure *anatum* stock.

At the time, the entire concept of captive breeding and release of any species was very controversial. Consequently we had so many people looking over our shoulder at everything we did we just couldn't afford to screw up. To ensure that any new procedure would be safe and reliable, we tested it first with species that were not so much at risk. For this reason we brought Gyrfalcons and Prairie Falcons into the project. They served as our experimental models.[31]

By 1972, a captive breeding facility had been established at Wainwright, Alberta. There, for the next five years, Fyfe, technician and fellow-falconer Phil Trefry, and their team worked patiently with the birds to devise the best means of encouraging productive pairing. Not only did they have to build up the stock to the point where there would be birds available for release, but they also had to find a way to return captive-bred birds successfully to the wild. The task was not an easy one. Despite evidence to the contrary, many observers maintained that captive breeding of falcons was impossible. Their persistent skepticism clouded the breeders' efforts with fear that the project might be terminated. At a critical point, however, captive-reared birds from Wainwright that had been released in Edmonton returned one spring and were found nesting at a site in northern Alberta.

"We were incredibly fortunate," remembers Richard Fyfe. "That one little bit of success lifted an enormous weight from our backs by proving that captive breeding would work as a strategy for reintroduction."[32]

It was with no small satisfaction that CWS Director General Alan Loughrey was able to report, in 1978, that "the experimental phase of the Peregrine Falcon Recovery Program — captive breeding and subsequent release of the progeny — has been successfully completed. We can now initiate an operational program."[33] In 1979, 34 peregrines were released at selected sites in western and central Canada. Between 1980 and 1983, close to 100 birds a year were produced for release, and the program was extended to include releases in New Brunswick and Nova Scotia.

Just when success seemed assured, the project encountered an unexpected obstacle. The rarity of the peregrine and the fact that it is prized by falconers around the world had resulted, in the 1960s and 1970s, in the illegal harvesting and trafficking of eggs and young from nests in Canada. In 1970, Glen Smith had reported that the illegal take from British Columbia was substantial — as many as 14 birds from the Queen Charlotte Islands in 1969, and a like number from eyries elsewhere along the coast.[34] By the early 1980s, American and Canadian law enforcement officers had devised Operation Falcon, an elaborate scheme to entrap illicit falconers and dealers and to trace the routes and methods they used to acquire and export birds.

In contrast to this shady trade, the CWS Peregrine Falcon breeding and recovery program at Wainwright was wholly legitimate. Its origins were aboveboard, and its activities open to public scrutiny. Nevertheless, even as Fyfe and his associates were making history with their ground-breaking work in captive breeding, suspicions were cast in their direction. Some investigators held to the discredited belief that captive breeding of falcons was impossible.[35] Therefore, they reasoned, the CWS program must be a cover for illegal trade in an endangered species under the very noses of the wildlife authorities.

Tony Keith was working in Edmonton in 1984, as Acting Director of the Prairie and Northern Region of CWS. To him fell the unhappy duty of having to respond to these allegations. It was proposed to him that a review of the Wainwright breeding records by CWS enforcement officers would dispel the rumours, demonstrate the integrity of everyone involved, and bring the matter to a close. This seemed like a sensible precaution at the time, and ultimately an exhaustive audit of the entire operation, as well as subsequent enquiries by provincial wildlife officials and the RCMP, proved unequivocally that the suspicions were groundless.[36] That is not to say that they were harmless. The spirit of mistrust in which the investigations had been initiated was not easily dispelled. It weighed heavily on Richard Fyfe. By the time it was over, even though his integrity was wholly vindicated, he felt so drained and disheartened that he chose to retire.

Fortunately, the program he had built continued to produce birds for release by federal and provincial wildlife authorities for another 10 years. Geoff Holroyd had worked with Fyfe on the program and now succeeded him in directing it, supported by biologist Ursula Banasch and by technicians Phil and Helen Trefry, whose skill in handling the birds had been instrumental to the success of the Wainwright breeding program virtually from its inception. Finally, in 1995, it was determined that there were enough free peregrines to assure reproductive continuity in the wild. *Anatum* peregrines were nesting throughout their former range, from the Rocky Mountains to the Bay of Fundy. The Wainwright facility was shut down, having raised more than 1500 peregrines for release over a period of 25 years. The breeding stock was offered to private individuals who wanted to breed them under licence. Richard Fyfe now keeps two pairs of Peregrine Falcons and a pair of Prairie Falcons at his home outside Edmonton:

> I was privileged to work on this project and to work with the calibre of staff we had. The wisdom of dedicated falconers — Phil Trefry in particular — was invaluable. To have been part of something like that is really special. My greatest reward is that I can go out every year now and see free-flying peregrines and know that they're there because of what we did.[37]

Species Protection: A Broader View

The complexity — scientific, jurisdictional, and philosophical — of the peregrine recovery program illustrated clearly how the role and relationships of CWS were changing vis-à-vis other wildlife agencies. As the provinces and territories responded increasingly to management needs and public expectations within their own area of jurisdiction, it became evident that CWS, as the lead federal agency, could not reasonably be expected to bear the full responsibility for endangered species. Direct federal authority was essentially limited to migratory birds and to wildlife in national parks. Provincial powers limited the ability of CWS to address challenges facing species or ecosystems that fell outside those closely defined limits, yet the emphasis among wildlife scientists around the world was shifting increasingly to reflect concerns about regional and global biodiversity. Canada needed a coordinated national approach to species protection.

As early as 1967, Nick Novakowski, in the role of Staff Specialist in Mammalogy, was urging greater collaboration among agencies. Citing the preamble to the IUCN charter, which links the impoverishment of natural resources and the lowering of human standards of living, he wrote:

Preliminary efforts to breed and rear Peregrine Falcons in captivity were so successful that by January 1973 construction workers were putting the finishing touches on vastly expanded outdoor flight pens at Wainwright, Alberta (Photo credit: R. Fyfe).

> We have given too little thought to this in our own country because we are still actively involved in resource exploitation....[T]he...threat of extermination of an animal [receives] little attention, not because we have no concern but because the animal in question may have little value in an economic sense....and, failing a large publicity build-up such as was and is afforded the whooping crane, public sentiment is lacking, or apathetic.
>
> In the event that this apathy may be due to ignorance of the facts we feel it is our responsibility and the responsibility of all wildlife agencies and organizations across Canada to make known certain facts about animal species in danger of extinction so that remedial methods can be applied in time and with public awareness and support.
>
> ...Obviously we need more involvement in this project by as many interested people as we can find....[38]

In 1970, Theodore (Ted) Mosquin, who had recently assumed editorship of the *Canadian Field-Naturalist*, joined the discussion. In a statement of editorial policy, he announced that the journal would adopt an increasingly proactive role "in helping Canadians protect or manage our living resources much more wisely than has been done in the past."[39] In a practical demonstration of the policy, the same issue contained a series of articles listing rare and endangered Canadian fishes (Donald E. McAllister), amphibians and reptiles (Francis R. Cook), mammals (N. S. Novakowski), and birds (W. Earl Godfrey).[40]

The theme of endangered wildlife and, in general, the practice of interagency cooperation in developing approaches to the problem continued to be explored constructively for the next several years, encouraged, no doubt, by the negotiation of the Convention on Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1973 and its subsequent ratification by Canada in 1975 (see Chapter 10). It was not until 1976, however, that a formal call for domestic action was sounded. That year, the Federal–Provincial Wildlife Conference, held on 6–8 July in Fredericton, New Brunswick, adopted a recommendation put forward by Nick Novakowski and Tony Keith to:

> ...strike a standing committee consisting of representatives of the federal and provincial governments and appropriate conservation and scientific organizations for the purpose of establishing the status of endangered and threatened species and habitats in Canada.[41]

Such recommendations seldom materialize spontaneously. In this case, the proposal came from a national symposium on the theme "Canada's Threatened Species and Habitats," which had been held in Ottawa about six weeks earlier under the joint sponsorship of the Canadian Nature Federation and the World Wildlife Fund. The symposium, in which Ted Mosquin had played an active role, had called for a broadening of the Canada Wildlife Act to include any species of flora or fauna in Canada and for federal–provincial collaboration to support research into species at risk and the creation of "significant nature reserves for the purpose of protecting unique and irreplaceable natural ecosystems."[42] Although a number of voluntary environmental groups and some Members of Parliament were pressing for federal endangered species legislation, it was evident to CWS officials that such an approach would be anathema to the provinces. Instead, in discussions with the provincial wildlife directors, Alan Loughrey and Tony Keith won support for a national effort to determine status, without infringing on the legal prerogative of each province to manage wildlife within its boundaries (see Chapter 10).[43]

Action on the recommendation followed. On 24 March 1977, an extraordinary meeting of federal and provincial wildlife officials and representatives of interested nongovernment organizations was held in Ottawa to determine the feasibility of such a committee. Support for the concept was unanimous, and it was decided that:

- a permanent standing committee would be organized;
- the chair would be elected by the committee and would rotate biennially; and
- a permanent secretary would be appointed.

Tony Keith, then Director of the Wildlife Management Branch of CWS, was selected as *pro tem* chair of the committee.[44]

Six months later, on 27 September 1977, the inaugural meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) took place. Participating government organizations included CWS, the National Museum of Natural Sciences, Parks Canada, provincial and territorial representatives from British Columbia, Yukon, Alberta, Northwest Territories, Saskatchewan, Manitoba, Ontario, and Quebec. The Canadian Wildlife Federation and the Canadian Nature Federation were the two participating voluntary organizations in the first year of COSEWIC activity.

At its first meeting, the committee designated Nick Novakowski as permanent secretary and appointed a subcommittee to address the task of developing a uniform terminology and format for status reports. At a second meeting, on 2 May 1978, the committee considered and approved definitions of five national status categories for species of wildlife: rare, threatened, endangered, extirpated, and extinct. Based on these categories, the participants also approved status designations for 19 species and subspecies as follows:

Rare:
Trumpeter Swan
Caspian Tern
Peregrine Falcon (*pealei*)
Black-tailed Prairie Dog

Threatened:
White Pelican
Peregrine Falcon *(tundrius)*
Piping Plover

Endangered:
Peregrine Falcon (*anatum*)
Greater Prairie-Chicken
Whooping Crane
Eskimo Curlew
Vancouver Island Marmot
Sea Otter
Eastern Cougar
Wood Bison

Extirpated:
Swift Fox
Black-footed Ferret

Not in any category:
Gyrfalcon
Double-crested Cormorant

The committee assigned various member agencies to prepare status reports on a further 15 species. In its annual report, COSEWIC asked that the delegates to the 42nd annual Federal–Provincial Wildlife Conference approve its operating procedures and advise on the addition of invertebrates and plants to the wildlife groups it might consider.[45]

By 1979, after two years of activity, Tony Keith reported that COSEWIC had assigned status to 13 more species, bringing the cumulative total to 32, and that Dalton Muir of CWS had been appointed as the new Permanent Secretary. Having completed an initial review of most of the species of birds and terrestrial mammals in Canada that were known to be in trouble, the committee was turning its attention to the status of marine mammals, reptiles, amphibians, and fish. The importance of promoting public awareness of the plight of species at risk was also a topic of growing concern. As Keith stated in his closing remarks:

> Your Committee on the Status of Endangered Wildlife is off and running. It has touched an astonishing chord of enthusiasm in experts across the country, who have contributed many hundreds of hours to producing a really outstanding series of status reports....Through the launching of the summary sheet program, the committee hopes that all its member organizations will participate in an effort to let Canadians know which of their wildlife co-inhabitants are in difficulty, and why.[46]

There was a downside to the situation in which COSEWIC found itself, however, and that was, as Tony Keith expressed it, that "operations have been run so far on love and a shoestring."[47] The point was put more forcefully the following year by Monte Hummel, Executive Director of the World Wildlife Fund (WWF) of Canada, who stated:

> We [i.e., WWF] believe there is a serious mismatch between government policy and public interest in wildlife conservation in Canada. In our experience, the Canadian public is concerned, particularly about conserving so-called non-game species. To date, the public has backed up this concern with dollars in support of

organizations such as ours. Government policy and spending, on the other hand, indicate either that federal and provincial officials are unaware of this great public interest, or they are deliberately ignoring it.

What evidence does WWF (Can) have for claiming there is this very tangible public concern and support for wildlife conservation in Canada? Last year, our general donations more than doubled. Our total income more than tripled....The Canadian Wildlife Federation recently organized a direct mail campaign regarding endangered species to 100 000 Canadians. They got a response, *with donations*, from over 20%. That's more than 10 times the response which marketing experts expect....

It is time that a serious effort was made to conserve the wild genetic resources of Canada. This has been recognized and tangibly supported by the Canadian public, but not by politicians or a large enough number of government officials.[48]

That very year, COSEWIC received welcome financial assistance from the Richard Ivey Foundation in the form of a three-year grant of $16 500 per annum to support the preparation of status reports. When the term of this funding arrangement came to an end, it was the World Wildlife Fund (Canada) that came through with a formula to match the contributions of other COSEWIC members for three more years, on a declining scale of $20 000, $15 000, and $10 000.[49]

How far COSEWIC had progressed by 1983 was clearly demonstrated in an operational audit report tabled by Joe Bryant, then Acting Director of Wildlife Research and Interpretation. A total of 78 status reports had been tabled, and designations had been assigned to 64 species, including nine fish and eight plants. Although most of the member organizations participated regularly in meetings, the operational viability of the committee was largely dependent on CWS, which had contributed a total of $186 700 in cash and kind — approximately 40% of the total for the first five years. As far as funding for research was concerned, the World Wildlife Fund (Canada) had some justification in feeling it was carrying more than a fair share of the load. The voluntary organization had secured or contributed more than one-third of the total funding for the commissioning of status reports.[50]

Nonetheless, by identifying and publicizing endangered species, COSEWIC was inevitably creating a public demand that something be done to protect them. In 1985, Chuck Dauphiné, whose previous position in mammal research had been eliminated by cutbacks to the Research and Interpretation Branch, was appointed Coordinator of Endangered Species. His task was to pull together all the different CWS initiatives dealing with species at risk and establish a national context for them.

Prior to that time, as the accounts of work with the Trumpeter Swan, Whooping Crane, Peregrine Falcon, and Wood Bison (see Chapter 4) have illustrated, recovery work had proceeded largely on an ad hoc basis. Over the next few years, CWS identified biolo-

Meticulous records were kept through every stage of development at the CWS captive breeding facility at Wainwright, Alberta. Here, Peregrine Falcon eggs are weighed by Phil Trefry. Harry Armbruster followed Phil in 1977 (Photo credit: R. Fyfe).

gists in each region who were well positioned to play lead roles in strategic recovery planning. Geoff Holroyd expanded on his work with peregrines to encompass raptors in general and became chair of the Burrowing Owl Recovery Team. Bruce Johnson became general coordinator for endangered species work in the Atlantic Region, took part in the peregrine release program, and chaired the Eastern Piping Plover Recovery Team. Pierre Laporte performed a similar role in the Quebec Region with these two species and for the program as a whole. In the Pacific and Yukon Region, Rhonda Millikin was a key contact.

While some became regional coordinators of endangered species work, others concentrated on single species. Lu Carbyn, for instance, applied his vast experience with Wolves to the Swift Fox reintroduction program. Frank Miller, a Caribou specialist, documented the alarming decline of the Peary Caribou. Ian Goudie built the case for listing the east coast population of the Harlequin Duck. All across the country, CWS biologists devoted time and talent to the urgent work of determining what portion of

Canada's wildlife was in trouble, and what could be done about it.

Eleven years into the COSEWIC program, in 1988, Tony Keith, who had originally been chosen to sit *pro tem*, retired as Chair. He was succeeded in that role by W. T. (Bill) Munro of British Columbia, and shortly thereafter Chuck Dauphiné became the permanent CWS representative on the Committee. During Keith's term of office, the group had assigned status designations to 164 species, including 33 birds, 23 terrestrial mammals, 13 marine mammals, two reptiles and amphibians, 40 fish, and 53 plants. With the passage of time, some designations had been changed. The Wood Bison had been downlisted from "endangered" to "threatened," and the White Pelican had been removed from the list entirely. Whooping Crane numbers were increasing slowly but steadily, and the captive breeding and release program for the Peregrine Falcon appeared to be headed for success. CWS had been collaborating closely with provincial and university-based scientists on a project to reintroduce the Swift Fox to areas of the Prairie provinces from which it had been extirpated more than 50 years before.

Still, the number of species known to be threatened and endangered continued to climb faster than could be offset by this handful of promising success stories. In part this was because of habitat deterioration and other stresses on wildlife; in larger measure, however, it reflected the fact that only a small fraction of the wildlife species native to Canada had been assessed. It was only to be expected, as the review process continued, that some species would be found to be at risk among the many whose status had hitherto been unknown. The mounting files were really a measure of the progress that the Committee was making towards an inventory of Canada's biodiversity. Although the list of species at risk got longer with each year, so did the list of those confirmed as "not in any category."

In 1989, CWS launched a major public education initiative through the State of the Environment Reporting Directorate of Environment Canada. *On the Brink: Endangered Species in Canada* was an attractively illustrated, hard-cover volume summarizing and interpreting the work of COSEWIC and the status reports on which it had made decisions up to that time. The work combined scientific content with a popular interpretive style and received positive reviews across the country.

In looking back over the first decade and more of coordinated study of species at risk, it was evident to the participating sponsors of COSEWIC that, in addition to the cataloguing and interpretive work that was going on, a more purposeful strategy of intervention on behalf of endangered species was required. As the authors of *On the Brink* pointed out,

> In COSEWIC, Canadians have established a mechanism for identifying plants and animals that are at risk of extinction. COSEWIC's role, however, is only to evaluate and list or de-list species; it has no authority for wildlife or environmental management, and the list of species it publishes has no legal status....Over the past several years it has become evident that a more active approach is required to ensure that the needs of listed species will be addressed, and that action for recovery will be undertaken where feasible.[51]

A concept for a proactive response to this need had been articulated in the mid-1980s by Jim Foley, who, following termination of the CWS interpretive program, had undertaken a series of wildlife and environmental policy assignments. His idea was picked up by Chuck Dauphiné, who collaborated with Hugh Monaghan, Director of Fish and Wildlife in the Yukon territorial government, to finalize a detailed proposal. In 1988, their proposal was adopted. Federal, provincial, and territorial agencies responsible for the many facets of wildlife management in Canada established an umbrella organization and strategy to develop and implement recovery plans, at least for threatened and endangered vertebrates. The acronym of the program, RENEW, was suggested by Geoff Holroyd and reflected its objective — the Recovery of Nationally Endangered Wildlife.

CWS played a lead role in RENEW. Director General Tony Clarke served as its founding chair, and the agency offered office space and a secretariat. Sylvia Normand had been secretary to COSEWIC. Now, she provided essential support services to two national bodies instead of one. Comprising essentially the same government and nongovernment membership as COSEWIC, RENEW provided a forum for cooperative action. It was also consistent with the aims of the Convention on Biological Diversity, which Canada ratified in 1992 in support of global goals of genetic, species, and ecosystem diversity.

The participants in RENEW endorsed an ambitious set of guiding principles:

- That no endangered species will be allowed to become extinct or extirpated.
- That no new species will be allowed to become threatened or move from threatened to endangered.
- That extirpated species will be reintroduced to Canada where feasible.
- That, where feasible, recovery programs will be undertaken in a way that will remove species from threatened, endangered, or extirpated status.
- That recovery plans will be prepared for all threatened and endangered species under RENEW's auspices.[52]

In order to sustain public interest and support for this vital work, Chuck Dauphiné began editing an occasional newsletter, *Recovery/Sauvegard,* in 1989. Drawing on the knowledge of recovery specialists from CWS and other agencies, the publication aimed to keep readers abreast of progress and priorities in wildlife recovery programs throughout Canada.

From the outset, there was much progress on which to report. Less than two years after RENEW was launched, recovery teams had been established for 14 of the 28 terrestrial vertebrate species then listed by COSEWIC. An estimated $2.23 million, supplied variously by the RENEW member organizations and a wide range of other sponsors, had been spent on recovery actions (fall 1989 to fall 1990).[53] Nine years into the program, Steve Curtis, Chairperson of RENEW and Associate Director General of CWS, reported that a total of 33 species recovery teams were active. CWS staff were members of 25 of these teams and chaired 16 of them, primarily, though not exclusively, those that dealt with migratory birds. In 1996–1997, spending on RENEW species totalled $3.7 million, and again the funds came from a wide coalition of organizations and institutions.[54]

An interesting evolution in the approach to species recovery is evident in the fact that one team, headed by CWS biologist Mike Cadman, developed a combined recovery strategy for two species, the Hooded Warbler and the Acadian Flycatcher, which share similar habitat requirements in the Carolinian ecozone of southwestern Ontario.[55] Another promising multispecies initiative took shape in British Columbia, where the South Okanagan Ecosystem Recovery Team was established in 1997 to address the needs of a variety of species, including the Pygmy Short-horned Lizard, Sage Thrasher, White-headed Woodpecker, and Yellow-breasted Chat. CWS members of this team were Pam Krannitz and Rhonda Millikin of the Pacific and Yukon Region.[56]

There was good news, too, regarding a number of creatures that had become icons of species protection over the years. Baird's Sparrow was delisted by COSEWIC on the basis of evidence that the population of this prairie passerine was much larger than had been known when it was designated as threatened in 1989. The Ferruginous Hawk, downlisted from threatened to vulnerable in 1996, continued to benefit from ongoing efforts to monitor and secure habitat and nest sites. A census conducted in 1996 found 289 Swift Foxes, strong evidence that a viable breeding population of this extirpated species has been successfully reintroduced to the Canadian prairies.[57]

The expansion of RENEW through the 1990s was reflected in an expansion of CWS resources dedicated to endangered species. In 1985, Chuck Dauphiné occupied the sole headquarters position allocated to this field of work. Before the end of the decade, his role and that of the COSEWIC/RENEW secretariat were both encompassed by the new Endangered Species Division headed by Tim Lash. Lash was succeeded in this job, first by Lynda Maltby and subsequently by Eleanor Zurbrigg when Maltby headed up the Biodiversity Protection Branch. By 1997, staff of the Endangered Species Division were responsible for routine coordination of CWS involvement with COSEWIC (Chuck Dauphiné) and RENEW (Simon Nadeau). They also provided the secretariat of both programs, under Sylvia Normand, and performed scientific duties stemming from Canada's participation in CITES (see Chapter 10). In addition, as the 1990s advanced, the division found itself fully engaged in the task of developing Canada's first national endangered species act.

Wild peregrine eggs with developing embryos had to be maintained at the right temperature during transport from the field to the breeding facility at Wainwright. Here Richard Fyfe makes ingenious use of styrofoam inside an attaché case, a hot water bottle, and a thermometer to ensure safe arrival of the eggs for hatching (Photo credit: CWS).

As individual and interagency initiatives gained ground — and publicity — for the recovery of particular species and spaces, legislation to support these efforts was one area where some observers perceived policy and practice to be lagging behind. For more than 20 years, the need for a uniform law to protect endangered species across Canada had been raised periodically at Federal–Provincial Wildlife Conferences, at meetings of nongovernment environmental organizations, by members of Parliament, and in the news media. In 1992, the desire to see significant national leadership on this issue came sharply into focus with a submission to the Parliamentary

Standing Committee on the Environment. The brief was sponsored jointly by the World Wildlife Fund and the Canadian Nature Federation (both members of COSEWIC and RENEW), the Canadian Parks and Wilderness Society, the Sierra Club of Canada, and the Canadian Environmental Law Association and was endorsed by the Canadian Bar Association. It challenged conventional government thinking directly, stating, "Environment Canada has determined, through a technical interpretation of the Convention, that no new legislation is needed to implement the biodiversity convention. That interpretation, in our view, is simply wrong, particularly in the area of endangered species."[58]

The movement in favour of endangered species legislation gained added momentum in 1993, when a CWS report based on data gathered by Statistics Canada revealed that 83.3% of Canadians attached high (54.4%) or moderate (28.9%) importance to the preservation of endangered or declining wildlife.[59] The message was virtually the same as that which the World Wildlife Fund had delivered to COSEWIC in 1980.

Further evidence of public support was derived from a focus group on "Managing Wildlife at Risk: Do We Have the Right Tools?" This exercise, coordinated by Environment Canada, produced 10 recommendations on legislation and policy, including the following:

- That all provinces should enact comprehensive legislation...to ensure the protection of species, ecological communities, and ecosystems.
- That provinces having existing endangered species legislation should upgrade their legislation to reflect these standards.
- That the federal government should pass an act equivalent to the provincial acts to cover species within its jurisdiction...[and to] frame minimum standards for designation and protection of endangered species of national significance and their habitats, and for the application of recovery strategies.[60]

The issue passed a critical turning point in February 1996, when the Speech from the Throne included a specific commitment to introduce endangered species legislation. Shortly thereafter, the draft framework for such an act was released.

Throughout that spring, CWS played an active role in coordinating meetings of stakeholders in every province. The participants, representing government, business, institutional, and voluntary sectors, were invited to offer constructive criticism of the document with a view to identifying weaknesses and areas of conflicting interest. Reactions were vigorous and varied. Provincial officials were cautious of any move that might infringe on their jurisdiction. Many environmentalists felt the proposed legislation fell short of their hopes for an act that would authorize strong intervention across jurisdictional boundaries to protect species at risk. Some representatives of resource-based industries expressed concern that the law would impede their ability to manage access to and extraction of their raw materials. Among ecologists and wildlife biologists, worries were expressed that a species-centred wildlife conservation policy might promote a narrow view of wildlife that could undermine progress towards management based on broader principles of ecosystem diversity.

Clearly, nothing would satisfy all the stakeholders on all points. Rare indeed is the law that does. Taking the diversity of views and interests into account, the CWS endangered species team, headed by Associate Director General Steve Curtis, worked long and hard with the provincial agencies to develop two documents, a national accord and a national framework for the protection of species at risk.

The accord acknowledged several important principles, including the following:

- that species do not recognize jurisdictional boundaries, and cooperation is crucial to the conservation and protection of species at risk;
- that conservation of species at risk is a key component of the Canadian Biodiversity Strategy, which aims to conserve biological diversity in Canada;
- that lack of full scientific certainty must not be used as a reason to delay measures to avoid or minimize threats to species at risk.[61]

Further, it announced the intention to coordinate the efforts of governments in this field through a Canadian Endangered Species Conservation Council, to recognize COSEWIC as a source of independent advice on the status of species at risk, and to establish complementary legislation and programs to provide "effective protection of species at risk throughout Canada..."[62]

On 2 October 1996, Canada's ministers responsible for wildlife met in Charlottetown and approved the accord in principle, thus engaging each jurisdiction to cooperate in ensuring that legislation and programs would be set in place to complement the provisions of a federal law governing endangered species. Less than a month later, on 31 October 1996, the Honourable Sergio Marchi, then federal Minister of the Environment, tabled Bill C-65 in the House of Commons. It was the first comprehensive, national endangered species legislation in Canada's history.

At that point, history intervened. Before the Bill could be passed, a federal general election was called, and the Canada Endangered Species Protection Act died on the Order Paper. In the interim, however, the proposed legislation had been subjected to another round of close scrutiny by Parliament and by the many witnesses who appeared to discuss its provisions before the Standing Committee on Environment and Sustainable Development. It appeared highly likely, as the Wildlife Service celebrated its 50th anniversary in the fall of 1997, that a modified Bill would be resubmitted and approved before the year 2000.

Notes

1. P. A. Taverner, *Birds of Canada*, revised edition (Toronto: Musson, 1947), page 76.
2. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), page 321.
3. Graham Osborne, "Winged grace," *Equinox* 70 (August): 64–73 (1993).
4. L. Shandruk, personal communication, interviewed at Edmonton, 3 December 1996.
5. E. Kuyt, *Whooping Crane* (Ottawa: Canadian Wildlife Service Hinterland Who's Who, 1993).
6. Kuyt, *Whooping Crane*. (See note 5)
7. Lewis, *Lively*, page 364. (See note 2)
8. N. Novakowski, personal communication, interviewed at Ottawa, 27 November 1996.
9. E. Kuyt, personal communication, interviewed at Edmonton, 3 December 1996.
10. N. S. Novakowski, *Whooping Crane Population Dynamics on the Nesting Grounds, Wood Buffalo National Park, Northwest Territories, Canada* (Ottawa: Canadian Wildlife Service Report Series, Number 1, 1966), 20 pages.
11. Letter from D. Munro in the possession of E. Kuyt.
12. Kuyt, personal communication. (See note 9)
13. Novakowski, *Whooping Crane Population Dynamics*. (See note 10)
14. E. Struzik, "Cry of the Whooper," *Equinox* 63 (May/June): 36–47 (1992).
15. Kuyt, *Whooping Crane*. (See note 5)
16. Kuyt, personal communication. (See note 9)
17. Kuyt, personal communication. (See note 9)
18. Kuyt, personal communication. (See note 9)
19. W. Earl Godfrey, *The Birds of Canada*, revised (Ottawa: National Museum of Natural Sciences, 1986), page 150.
20. V. E. F. Solman, "Biocides and wildlife" in *Minutes and Papers of the 27th Federal–Provincial Wildlife Conference*, 18–19 April 1963, Ottawa (Ottawa: Canadian Wildlife Service, 1963), page 47.
21. F. G. Cooch, "Current developments in the biocide field" in *Proceeding and Papers of the 28th Federal–Provincial Wildlife Conference*, 18–19 June 1964, Charlottetown (Ottawa: Canadian Wildlife Service, 1964), page 33.
22. Richard Fyfe, "Birds of prey and the practice of falconry in Canada" in *Summary Notes and Papers of the 30th Federal–Provincial Wildlife Conference*, 12–14 June 1966, Quebec City (Ottawa: Canadian Wildlife Service, 1966), page 27.
23. Recommendation Number 8 in *Summary Notes and Papers of the 30th Federal–Provincial Wildlife Conference*, 12–14 June 1966, Quebec City (Ottawa: Canadian Wildlife Service, 1966), page 18.
24. Richard Fyfe, "Canadian Wildlife Service involvement with birds of prey" in *Transactions of the 36th Federal–Provincial Wildlife Conference*, 11–14 July 1972, Dartmouth, Nova Scotia (Ottawa: Canadian Wildlife Service, 1972), page 73.
25. J. A. Keith, "Toxic chemical research by the Canadian Wildlife Service" in *Transactions of the 34th Federal–Provincial Wildlife Conference*, 14–16 July 1970, Yellowknife, Northwest Territories (Ottawa: Canadian Wildlife Service, 1970), page 38.
26. Tom J. Cade and Richard Fyfe, "The North American Peregrine survey, 1970," *The Canadian Field-Naturalist* 84(3): 231–245 (1970).
27. Fyfe, "Canadian Wildlife Service involvement." (See note 24)
28. Cade and Fyfe, "The North American Peregrine survey." (See note 26)
29. W. G. Smith, "Management and conservation of raptorial birds in British Columbia" in *Transactions of the 34th Federal–Provincial Wildlife Conference*, 14–16 July 1970, Yellowknife, Northwest Territories (Ottawa: Canadian Wildlife Service, 1970), page 33.
30. R. Fyfe, personal communication, 16 September 1997.
31. Richard Fyfe, personal communication, interviewed at Edmonton, 3 December 1996.
32. Fyfe, personal communication. (See note 31)
33. A. Loughrey, "Report on the Canadian Wildlife Service" in *Transactions of the 42nd Federal–Provincial Wildlife Conference*, 27–30 June 1978, Quebec City (Ottawa: Canadian Wildlife Service, 1978), page 47.
34. Smith, "Management and conservation." (See note 29)
35. Paul Mackay, *The Cowboy and the Pilgrim* (New York: McGraw-Hill, 1989).
36. J. A. Keith, personal communication, telephone interview, 25 July 1997.
37. Richard Fyfe, personal communication, December 1996.
38. N. S. Novakowski, "Conservation of rare and endangered species of mammals in Canada" in *Transactions of the 31st Federal–Provincial Wildlife Conference*, 11–13 July 1967, Ottawa (Ottawa: Canadian Wildlife Service, 1967), page 73.
39. Theodore Mosquin, "Editorial policy of the *Canadian Field-Naturalist*," *The Canadian Field-Naturalist* 84(1): 3 (1970).
40. cf. *The Canadian Field-Naturalist* 84(1): 5–26 (1970).
41. Recommendation Number 6 in *Transactions of the 40th Federal–Provincial Wildlife Conference*, 6–8 July 1976, Fredericton (Ottawa: Canadian Wildlife Service, 1976).
42. T. Mosquin, "Report of the Canadian Nature Federation" in *Transactions of the 40th Federal–Provincial Wildlife Conference*, 6–8 July 1976, Fredericton (Ottawa: Canadian Wildlife Service, 1976), page 46.
43. J. A. Keith, personal communication, December 1997.
44. *Transactions of the 41st Federal–Provincial Wildlife Conference*, 5–7 July 1977, Winnipeg (Ottawa: Canadian Wildlife Service, 1977), page 13.
45. J. A. Keith, "Report of the Committee on the Status of Endangered Wildlife in Canada" in *Transactions of the 42nd Federal–Provincial Wildlife Conference*, 27–30 June 1978, Quebec City (Ottawa: Canadian Wildlife Service, 1978), pages 84–88.
46. J. A. Keith, "Report of the Committee on the Status of Endangered Wildlife in Canada" in *Transactions of the 43rd Federal–Provincial Wildlife Conference*, 26–29 June 1979, Regina (Ottawa: Canadian Wildlife Service, 1979), page 74.
47. Keith, "Report of the Committee." (See note 46)
48. Quoted in J. A. Keith, "Report of the Committee on the Status of Endangered Wildlife in Canada" in *Transactions of the 44th Federal–Provincial Wildlife Conference*, 24–27 June 1980, Ottawa (Ottawa: Canadian Wildlife Service, 1980), page 264.
49. J. A. Keith, "Report of the Committee on the Status of

Endangered Wildlife in Canada" in *Transactions of the 46th Federal–Provincial Wildlife Conference*, 1–4 June 1982, Whitehorse (Ottawa: Canadian Wildlife Service, 1982), page 284.
50. J. E. Bryant, "COSEWIC audit statement" in *Transactions of the 47th Federal–Provincial Wildlife Conference*, 28 June – 1 July 1983, Edmonton (Ottawa: Canadian Wildlife Service, 1983), pages 200–206.
51. J. A. Burnett, T. C. Dauphiné, S. McCrindle, and T. Mosquin, *On the Brink: Endangered Species in Canada* (Saskatoon: Canadian Wildlife Service and Western Producer Prairie Books, 1989), page 159.
52. Canadian Wildlife Directors, *RENEW Annual Report* (Ottawa: Minister of Supply and Services, 1990), page I.
53. Canadian Wildlife Directors, *RENEW Annual Report.* (See note 52)
54. RENEW, *RENEW Report #7* (Ottawa: Minister of Public Works and Government Services, 1997).
55. Mike Cadman, "Multi-species recovery takes flight," *Recovery: An Endangered Species Newsletter*, Spring 1997 (Ottawa: Canadian Wildlife Service, 1997).
56. RENEW, *RENEW Report #7.* (See note 54)
57. RENEW, *RENEW Report #7.* (See note 54).
58. Quoted in Canadian Wildlife Service, *Endangered Species Legislation in Canada: A Discussion Paper* (Ottawa: Environment Canada, 1994), page 5.
59. F. L. Filion, E. DuWors, P. Boxall, P. Bouchard, R. Reid, P. A. Gray, A. Bath, A. Jacquemot, and G. Legare, *The Importance of Wildlife to Canadians: Highlights of the 1991 Survey* (Ottawa: Environment Canada, Canadian Wildlife Service, 1993), 60 pages.
60. Quoted in Canadian Wildlife Service, *Endangered Species Legislation*, page 6. (See note 58)
61. National Accord for the Protection of Species at Risk in Canada (1996).
62. National Accord. (See note 61)

1987–1992: Going Green

As 1987 unfolded, a mood of celebration animated CWS. It was not only the 40th anniversary of CWS, but also the centenary of wildlife conservation in Canada as represented by the establishment of the country's first designated wildlife sanctuary, at Last Mountain Lake, Saskatchewan, in 1887. Posters, media events, and feature stories and columns in local and national newspapers focused the attention of Canadians on wildlife to an unprecedented degree.

Canadians were receptive. Public opinion research indicated high levels of interest in wildlife conservation and protection. Fern Filion's continuing analysis of data from CWS surveys demonstrated that wildlife-related activities, especially nonconsumptive ones such as photography, observation, and feeding, were growing particularly fast, far surpassing hunting and fishing in popularity.[1]

Information about wildlife and environmental topics in general seemed likely to remain a priority, as Environment Canada's Lands Directorate, incorporating the State of the Environment Reporting Branch and the Sustainable Development Branch, was transferred to CWS, joining Wildlife Toxicology and Surveys, Migratory Birds and Wildlife Conservation, and Program, Marketing and Operational Services under the umbrella of the Ottawa-based core agency. Although the merger seemed to have excellent potential, it lasted little more than a year. The CWS organizational chart for 1989 indicated a reversion to four headquarters branches: Wildlife Toxicology and Surveys, Migratory Birds and Wildlife Conservation, North American Waterfowl Management Plan Implementation, and Program Analysis and Coordination. State of the Environment Reporting was relocated to the Corporate Policy Group of the department, leaving behind the Habitat Conservation Division and a few other Lands Directorate staff within CWS. Wholly absent from the headquarters organizational charts of this period are all CWS field offices. The reorganization of 1986, in which responsibility for supervision of CWS regional operations had been shifted to Environment Canada Regional Directors General, resulted in a sharp division of roles.

CWS was deeply engrossed in preparing for two major world conferences in 1987. The Third Meeting of the Conference of the Parties to the Convention on Wetlands of International Importance (Ramsar Conference) was scheduled for Regina at the end of May. Just six weeks later, the Sixth Meeting of the Parties to the Convention on International Trade in Endangered Species (CITES Conference) occurred in Ottawa.

The keen public interest in wildlife, combined with international attention, effectively set the stage for a very important new initiative in 1990. That year, the federal government announced its "Green Plan," a wide-ranging strategy that was scheduled, over the next four years, to devote in excess of $3 billion to environmental projects. After a number of years of belt-tightening, it appeared that funding might once more be available to accelerate urgently needed wildlife conservation programs.

Generally, the idea of the Green Plan was well-received by the environmental community. A coalition of eight national groups with combined membership of over a million members reviewed the proposal and reported to the 1990 Federal–Provincial/Territorial Wildlife Conference. While some concern was expressed that the Green Plan lacked a long-term vision, the consensus was that it represented a good strategic framework for implementation of the new "Wildlife Policy for Canada" that would be submitted to wildlife ministers and approved that September. This view was underlined in a 1990 resolution that:

> The Canadian Federal–Provincial/Territorial Meeting recommends to the Minister, Environment Canada that the wildlife initiatives of the proposed "Federal Green Plan on the Environment" incorporate the twelve components of the National Policy as a conceptual framework for action.[2]

The wildlife policy, which Tony Keith of CWS had shepherded through labyrinthine negotiations for nearly a decade from conception to completion, did indeed provide a fertile framework for action. In 1991, David Brackett succeeded Tony Clarke as Director General of CWS; when he chaired the 1992 Wildlife Directors Meeting in Quebec City, the emerging wildlife-related issues on the table were sweeping and complex. The question of how to amend the Migratory Birds Convention was back on the table for discussion with the United States. The possibility of amendments to the Migratory Birds Convention Act and the Canada Wildlife Act was under consideration as well. Although the wildlife directors felt there was no need for national endangered species legislation, the topic was immediate enough, in relation to the Convention on Biodiversity, to evoke serious discussion. A summary of progress towards a National Enforcement Strategy foreshadowed major adjustments in the organization of federal wildlife enforcement activities.

The "National Wildlife Strategy," introduced by Environment Minister Jean Charest under the Green Plan on 29 November 1991, outlined how the federal government intended to implement its wildlife policy. The strategy, backed by a proposed budget of $34.9 million, encompassed five main thrusts. Wildlife science would benefit from stronger research programs in ecology and toxicology, including a Cooperative Wildlife Ecology Research Network. Wildlife diversity would be sustained through development and implementation of recovery plans for species at risk as well as increased support for cooperative management of habitat and expansion of volunteer-based nongame bird studies. Illicit trade in wildlife and wildlife products would be prosecuted under new legislation that was eventually passed in 1992 as the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act. Enforcement of wildlife protection measures would be supported by the addition of enforcement staff and the establishment of stiffer penalties for infractions (see Chapter 2). Finally, a concerted effort would be made to protect wildlife habitat, not only through joint ventures under NAWMP, but through an integrated forest conservation and management program, a national wildlife habitat network, and other initiatives.

Six of the new biologist and research positions created in the Wildlife Service under the Green Plan were filled by females. Connie Downes (National Wildlife Research Centre), Brenda Dale (Prairies), Rhonda Millikin (British Columbia), and Wendy Nixon (Yukon) joined CWS to coordinate bird population surveys. Kathy Martin (British Columbia) and Erica Dunn (National Wildlife Research Centre) were hired to focus on forest bird research.

As in society at large, the role of women professionals in the Wildlife Service was expanding greatly, after a slow and tentative start. The first female biologist at CWS, Sylvia Sykes, had only been hired in 1966. Her appointment was followed, about a year later, by that of Anne Currier, a veterinarian who was assigned to the pathology group. Others won jobs from time to time, but until the 1980s the hiring and promotion of women depended largely on the outlook of individual, male, senior managers. Some men were quite open to the idea of women participating in fieldwork; others were resolutely opposed. The few professionally trained women on the Wildlife Service staff — among them Myrtle Bateman, Barbara Campbell, Lynne (Allen) Dickson, Lynda Maltby, Iola Price, Anne Rick, and Isabelle Ringuet — often felt isolated and under greater pressure than their male colleagues to prove themselves. Some remember being actively discouraged from taking field positions or having difficulty getting technical support to analyze data. Like their male colleagues, however, they were happy to be working in their chosen field. Most simply took advantage of the opportunities that were offered and ignored doors that seemed firmly closed against them. The influx of women as a result of the Green Plan marked a definitive change in the male-dominated character of the Wildlife Service.

Another challenge in the midst of these emerging issues was the sense that the quality of communications between the government wildlife agencies and some of their nongovernment constituents might be deteriorating. The annual conference, as a national forum for discussion, was not functioning to the satisfaction of all participants. Since 1990, a new format had been adopted for these meetings. The wildlife directors would discuss their agenda in some depth at a two-day closed meeting. This was followed by a much shorter consultative encounter with the nongovernment organizations for an exchange of information.

The difference in the nature of the meetings was evident in the level of participation. In 1988, 249 people had registered to attend the 52nd Conference in Victoria, British Columbia. By contrast, only 25 attended the 1992 meeting in Quebec City. The richness of content and discussion that had been a hallmark of the former meetings, when closed sessions were briefer and far more delegates participated actively in issue-driven workshop and discussion sessions, was missing. The consensus of the 1992 consultation, after three years under the revised format, was that there was a clear need for change.[3]

Notes

1. F. L. Filion, S. Parker, and E. DuWors, *The Importance of Wildlife to Canadians: Demand for Wildlife to 2001* (Ottawa: Canadian Wildlife Service, 1988).
2. Resolution from Canadian Wildlife Directors' Meeting to the Minister of Environment Canada, 20 June 1990.
3. Minutes of the Meeting of Canadian Wildlife Directors and Nongovernmental Organizations, Quebec City, 18 June 1992.

CHAPTER 10. Defining the Rules: Wildlife Governance

On 22 May 1894, botanist and naturalist John Macoun stood before the Royal Society of Canada and stated bluntly, "The forests of the Dominion of Canada are one of its chief assets and one that it seems the aim of governments and individuals to annihilate as quickly as possible." From Nova Scotia to British Columbia, Macoun traced the westward advance of wanton deforestation, concluding the introductory section of his paper with the prescient words:

> Apparently there is little hope of a change, for viciousness, carelessness, cupidity and supineness of governments and people are responsible for this state of things which will continue until the trees are nearly all dead and the destruction of our noble forests all but completed; then when the end has come party parliamentarians will rise in their places and denounce all but themselves for having permitted such senseless and culpable destruction.[1]

Macoun's sentiments about the forests reflected a concern over the lack of governance in the field of natural resources that was already sufficiently widespread to stimulate positive action. As noted previously (see Chapter 1), national legislative initiatives to conserve and protect wilderness and wildlife in Canada began with the passage of the Rocky Mountains Park Act in 1885. It was followed in 1887 by the creation of North America's first waterfowl refuge at Long Lake (now Last Mountain Lake, Saskatchewan). The cause of wildlife gained additional momentum in 1909, when Sir Wilfrid Laurier appointed the short-lived Commission on Conservation (1909–1921), but the nation's biodiversity had already been significantly diminished by 1917, when the Migratory Birds Convention Act came into effect. That Act was the first to establish a national framework governing the use of wildlife, or at least of migratory birds, across Canada. Other wildlife issues, in lands under federal jurisdiction, were addressed in the Northwest Game Act, which had been passed in 1906 and underwent extensive revision in 1917.

The tireless work of Hoyes Lloyd, Supervisor of Wildlife Protection, and Chief Migratory Bird Officers Harrison Lewis, Robie Tufts, Dewey Soper, and Jim Munro did much to promote a new public awareness of the value of wildlife to Canada and Canadians (see Chapter 1). By the time the Dominion Wildlife Service was established in 1947, their efforts, combined with a variety of other initiatives, had achieved considerable progress towards the establishment of a comprehensive system of wildlife governance.

Probably the most important of those other initiatives was the inauguration of a series of federal–provincial conferences on wildlife. The domestic negotiations leading up to the Migratory Birds Convention had demonstrated the sensitivity of relations between federal and provincial authorities. In 1919, the Commission on Conservation and the Advisory Board on Wild Life Protection convened a gathering of federal and provincial ministers, senior wildlife officials, and fish and game associations. For most of the participants, it was their first opportunity to meet face to face with their counterparts from other jurisdictions.

The British North America Act, in Section 92.(16), granted the provinces exclusive jurisdiction to make laws in relation to "Generally, all Matters of a merely local or private Nature in the Province." Wildlife, it was assumed by the provincial governments, was one of those "Matters." In his address to the conference, however, Gordon Hewitt, one of the key negotiators of the Migratory Birds Convention, argued that, since so many wildlife species were migratory, it was beyond the capability of any single province or territory to act alone for their protection. Referring to the conference, he stated, "We shall never again have such an excellent opportunity of attaining, by mutual efforts, the ends for which we are individually striving, as we have now."[2]

The delegates took his words to heart, working out a far better understanding of their common purpose in the cause of conservation than they had previously shared. In this collaborative spirit, they resolved many of the outstanding objections to the Migratory Birds Convention Act. Other problems, especially those dealing with spring shooting and aboriginal hunting, were at least identified, even though their resolution would not be achieved for another three generations.

Federal–Provincial Conferences

The 1919 conference concluded with a recommendation that it become an annual event. It did not, but three years later, in 1922, another federal–provincial conference of wildlife officials, somewhat more restricted in its range and objectives, took place in Ottawa. Where the first meeting had been open to virtually anyone with a serious interest in conservation, this time admission was limited to federal and provincial officials directly concerned with game management. Still, the discussions, once again largely focused on the implementation of the Migratory Birds Convention Act and Regulations, were highly constructive. Over the next 25 years, 10 more such conferences took place, biennially at first and later at less regular intervals, in 1924, 1926, 1928, 1930, 1932, 1937, 1939, 1942, 1945, and 1947.

Thereafter, the Federal–Provincial Wildlife Conference became an annual event and, for more than 75 years, in a variety of locations and formats, enabled federal and provincial authorities as well as nongovernment organizations to discuss, explore, and debate issues of wildlife governance in a forum that has remained relatively free of political manoeuvring and posturing for the media. The results were generally of great value to the amicable and constructive development of wildlife management policies and practices in Canada.

Even before the Wildlife Service was created, the Wildlife Protection Office, under Hoyes Lloyd and subsequently Harrison Lewis, had provided the secretariat for the conferences. Lewis recognized the strategic value of this arrangement and, from 1948 to 1951, chaired the meetings himself. J. A. Hutchinson, Director of the National Parks Branch, occupied the chair from 1952 to 1955, to be succeeded by Bill Mair from 1956 to 1961 and in 1963. David Munro then assumed the leadership of the conferences (1962 and 1964–1968) and was followed by John Tener, his successor as Director General of CWS, who chaired the meetings from 1969 to 1973. In 1973, a review committee recommended discussion of whether the chair should rotate among the official representatives of the provinces and territories, and that idea was adopted. Nevertheless, the Wildlife Service continued to provide the secretariat and, until 1989, to publish the proceedings. For many years, Doug Pollock of CWS coordinated the myriad details that ensured continuity and coherence.

Initially, the conference dealt largely with details relating to the administration of the Migratory Birds Convention Act, establishing hunting seasons for migratory game birds and developing regulations and practices for the management and protection of waterfowl. Minutes of the meetings record recommendations about gun control and the types of guns and ammunition to be permitted, bag limits, the proper use of boats and blinds, the licensing of hunting guides, and the issuance of permits to take protective measures against game birds that are destroying agricultural crops. Already, though, broader conservation questions were emerging in the discussions. One resolution of the 1939 conference called for the imposition of a stamp tax on hunters of migratory game birds to raise funds for the creation of sanctuaries and the conduct of research and interpretation activities. Another 45 years would pass before this prophetic suggestion was implemented through the establishment of Wildlife Habitat Canada and the Wildlife Habitat Conservation Stamp in 1984.

In 1937 and 1939,[3] the delegates called for passage of a federal act that would assist the provinces in regulating the export of furs. The response to this request was commendably swift. The Game Export Act, governing the movement of dead game and fur within Canada but beyond the borders of the province of origin, was passed by Parliament in 1940 and received Royal assent on 14 June 1941. A resolution in 1948 warned of the need to prevent the pollution of waters frequented by migratory birds. Others, in 1949, called for the creation of a coordinating committee to deal with the protection and management of Caribou and for the participation of the federal government in controlling predation on Barren-ground Caribou by Wolves.

At the 1954 conference, a new topic was introduced. Recommendation number 6 requested:

> That the Department of Northern Affairs and National Resources be requested to place wildlife resources on a basis similar to that accorded forest, fishery and agricultural resources, if necessary through passage of a Wildlife Act, and that the Canadian Wildlife Service of that Department be empowered to carry out research and other activities in the whole wildlife field in the provinces....[4]

From the perspective of the decentralizing 1990s, the idea of provincial representatives requesting an increase in federal authority may seem novel indeed. In the 1950s, the resolution was partly an indication of mutual confidence and trust and partly a measure of how limited the provincial resources for wildlife protection and research really were. Among the provinces, only Ontario had invested significant resources in developing a diversified wildlife research capability, with well-equipped laboratories, fish hatcheries, and staff biologists to conduct field research. British Columbia was moving in the same direction, and other provinces would follow suit as resources permitted, but it took a good many years to reach the point where all could meet on an equal professional footing.[5]

The provincial delegates often called on CWS to take on responsibilities, such as predator control or pesticides research, that did not fall strictly within federal jurisdiction. Indeed, one resolution of the 22nd Federal–Provincial Wildlife Conference (1958) recommended outright "that each province make representation through appropriate ministerial channels to the Federal Government outlining its needs in wildlife management and the areas wherein federal assistance in this endeavour is required."[6]

At the same time, the provinces were wary of allowing a centralist point of view to dominate their deliberations. Until 1955, every Federal–Provincial Wildlife Conference had taken place in Ottawa. One of the recommendations adopted that year proposed that "in future the [conference] be rotated in different parts of Canada," and, thereafter, the location changed annually.

It was partly in order to ensure responsiveness to regional needs that the Wildlife Service was reorganized, in 1962, into eastern and western administrative regions for purposes of supervising field operations. The move was encouraged by the provinces, and David Munro, Acting Chief of CWS at the time, saw this as evidence that:

> The provinces wanted to relate to somebody that they thought understood their regional concerns. Probably

> that was true within CWS as well. Nobody in the field ever likes head office, and they thought having a local contact would be a good thing.[7]

With seven offices in the west and north (including Inuvik, Fort Smith, and Whitehorse) and five in the east, in addition to the Ottawa headquarters facilities, the Wildlife Service was deployed in almost every province and had ample opportunity for local contact with provincial agencies without losing the benefit of national coordination for key areas of programs and research.

Meanwhile, an increasingly consistent pattern of federal–provincial consultation was emerging on a wide range of matters where there was an overlap between national and regional concerns. The 1961 Resources for Tomorrow Conference had identified many such areas. Two of the background papers in particular dealt with the question of wildlife management and administration in a federal state. David Munro wrote a penetrating and judicious analysis of how the tangled thicket of legislative, regulatory, and administrative variation between the different provinces and territories impeded the effective management of wildlife populations.[8] Bill Mair addressed the larger challenge of outlining the need for a national wildlife policy. He left no doubt about his own opinion concerning the urgency of the matter:

> Viewing developments in the wildlife field in the last 15 years, and the economic forecasts for the future, I believe that we shall find ourselves in a completely untenable position unless major decisions on policy are made within the next five years and programs of implementation commenced within ten years. Continued increase of utilization at the present rate without more than concomitant growth of wildlife management programs (they are already inadequate) can only lead to destructive exploitation from which recovery will be painfully slow and costly.[9]

It is impossible to demonstrate conclusively, from the documentation at hand, just how complete a plan Mair and Munro had developed at this time for the wildlife policy developments of the following decade. Anyone reading the published proceedings of the federal–provincial conferences during the years when they served as chairmen must appreciate the skill with which both men introduced concepts and shaped consensus in that forum. There is no apparent reason to suppose that they were not employing the same talents on this occasion. Certainly, the subsequent evolution of policy suggests the presence of adept guidance behind the scenes.

Towards a National Wildlife Act

Less than three years after the Resources for Tomorrow Conference, the Canadian Council of Resource Ministers was established as a forum in which to discuss natural resource policies. Since many of the Resource Ministers were responsible for wildlife within their particular jurisdictions, the Canadian Council of Resource Ministers found itself dealing with many of the same issues as the Federal–Provincial Wildlife Conferences, but at a ministerial level.

The issue of a national wildlife policy, in particular, came to the ministers' attention within the year. In May 1965, the Council met in Victoria. At the end of that meeting, the Honourable Arthur Laing, Minister of Northern Affairs and National Resources, announced plans to implement a National Wildlife Program. In the months that followed, the program took shape. David Munro, now Director of CWS, played an important role in synthesizing federal wildlife concerns and developing a draft policy. As a result, in a speech to the Alberta Fish and Game Association in Banff on 5 February 1966, the Minister was able to outline in some detail his intention to introduce a Canada Wildlife Act and to institute a variety of measures favourable to the good governance of wildlife, including a habitat protection plan, an expansion of general wildlife research, and the introduction of a Canada Migratory Game Bird Hunting Permit. Mr. Laing was sensitive to the jurisdictional pitfalls of his proposed course of action. He addressed the federal–provincial dilemma in these terms:

> The Program is based on the premise that although wildlife is divided between Canada and the provinces, the critical status of some wildlife species and habitat calls for a National Policy on wildlife and a cooperative approach with the provinces to the problem of wildlife management. The Program reflects the Council's acknowledgment, in May 1965, that the Federal Government should take positive action for the conservation of migratory birds. The Program is flexible and permissive in respect to other wildlife....
>
> The thought behind the Act is that it would help crystallize an interest in wildlife in all parts of Canada and would facilitate an expression of opinion by Parliament. It would further public understanding of the problems of wildlife and set the scene for an expansion of the public's understanding of wildlife research and management.[10]

Two months later, on 6 April 1966, in a statement to the House of Commons, the Minister presented Canada's National Wildlife Policy and Program to the House of Commons.

The National Wildlife Policy and Program constituted the first serious Parliamentary consideration of wildlife administration since the passage of the Migratory Birds Convention Act. Especially significant was the fact that, in constitutional terms, it set out a very expansive view of the federal role in this field. It spoke not only of migratory birds, but of all wildlife, even addressing the question of how to manage transboundary species such as Caribou. As Tony Keith would observe years later:

> It laid the foundation for a lot of work in other areas as well, providing a solid foundation on which to build the toxics and interpretation programs. The policy statement

was a very important declaration of what the government intended to do. The Canada Wildlife Act didn't come till some years later, but we acted as if we had an act. It meant that the 1970s became the fastest period of growth in the history of the Service.[11]

Signs that wildlife had been elevated among the government's priorities included the promotion of CWS, soon after, to the status of a full Branch in the newly reorganized Department of Indian Affairs and Northern Development, and the provision of additional funding to sustain a much expanded federal role in wildlife habitat conservation. Additional government reorganization led to the creation of the Department of Fisheries and Forests in 1968–1969, the transfer of the Wildlife Service to this department in 1970–1971, and its inclusion in the further amalgamation of wildlife, forestry, lands, and inland waters within the Environmental Management Service component of a newly created Department of the Environment (i.e., Environment Canada). This sequence of administrative changes was sufficient to delay the drafting and passage of the Canada Wildlife Act, which was not proclaimed as law until 27 July 1973.

Two definitions at the beginning of the new act indicated the extent to which the perception and understanding of wildlife had evolved. "Wildlife," stated Section 2.(1), "means any non-domestic animal." And Section 2.(2) added, "All the provisions of this Act respecting wildlife extend to wildlife habitat." In fewer than 20 words, Parliament enlarged the scope of the national interest in wildlife from migratory birds to all wild creatures and the places in which they live. The Minister was henceforth authorized to:

- Carry out research on any wildlife species or its habitat, anywhere in Canada, either unilaterally or under the terms of an agreement with a province.
- Have federal public lands assigned to the purposes of wildlife research, wildlife conservation, or wildlife interpretation.
- Acquire or lease private lands for the same three purposes, with the constraint that if species other than migratory birds were involved, agreement of the affected province(s) would be required.
- Take measures, in cooperation with the provinces, "for the protection of any species of non-domestic animal in danger of extinction."
- Make agreements with the provinces to carry out wildlife research, conservation, or interpretation.
- Coordinate and implement wildlife policies and programs in cooperation with the provinces.
- Take measures to encourage public cooperation in wildlife conservation and interpretation.

A section permitting the acquisition of lands for wildlife conservation and protection gave legislative legitimacy to the CWS habitat program six years after it had been initiated under the National Wildlife Policy and Program (see Chapter 6). Another section, authorizing federal collaboration with the provinces to protect endangered species, led to the formation, in 1977, of COSEWIC.

The expansion of federal interest to cover any species of wild animal and its habitat did create some potential for conflict with the provinces. Director General Alan Loughrey acknowledged this in a memorandum written in November 1977:

Two long-time stalwarts of CWS, much of whose best work was done behind the scenes, are Doug Pollock (*l.*) and Steve Curtis (*r.*), seen here at Joe Bryant's retirement luncheon in 1983. Pollock, for years, was Director of Administration. Curtis, in a variety of senior posts, has devoted many years of his working life to securing the passage of key wildlife legislation, including a long-awaited endangered species act (Photo credit: J. Foley).

> There is a significant difference between the way the Act deals with wildlife research and the way it deals with wildlife conservation, and the point of this difference is to prevent the overlapping federal and provincial interests coming into conflict....
>
> Why the difference in treatment between research and conservation? Simply because measures to conserve wildlife, such as regulations controlling hunting or collecting, could not be enforced unilaterally for the same wildlife populations by both federal and provincial governments without the real likelihood of what the Department's legal advisors call "operating incompatibility"....On the other hand, it is difficult to imagine "operating incompatibility" between laws authorizing research, and so the federal government is authorized by the *Canada Wildlife Act* to carry out any wildlife research required to meet national needs, even though some of the populations concerned may also be the subjects of provincial research to meet provincial needs.[12]

International Arrangements

The Polar Bear Agreement

Canada was not alone in the world community of nations when it came to taking a broader view of wildlife in the 1960s and 1970s. The concerns reflected in the Canada Wildlife Act were also shaping international perceptions of the need for conservation. Postwar affluence had fuelled a demand for luxury consumer goods, including rare and exotic furs, animal skins, and ivory. Postwar technologies had enabled opportunistic adventurers around the world to penetrate previously inaccessible wilderness areas, travelling by aircraft, speedboat, all-terrain vehicle, and snowmobile, in order to obtain the prized products. Wildlife populations that had previously been left relatively untouched were suddenly exposed to serious, potentially disastrous, pressures.

A prime example of a species affected by this trend in northern Canada was the Polar Bear. Soaring demand and soaring prices triggered an unprecedented increase in the number that were killed for their hides in the 1960s. CWS Polar Bear biologist Ian Stirling has noted that although the giant white bears had long been considered a special quarry, hunting pressure rose significantly through the 1960s.

> Through the 1950s and particularly during the 1960s, the rapidly increasing value of polar bear hides in North America and Europe, coupled with the increasing use of oversnow machines, stimulated unprecedented increases in the numbers of polar bears reported killed. For example, in Alaska, the trophy kill alone increased from 139 in 1961 to 399 in 1966. In Canada, between 1953 and 1964, the recorded harvest fluctuated between 350 and 550, while in 1967 it suddenly jumped to 726. The records are incomplete in most countries, so we will never know the actual number of bears killed.[13]

In 1965, specialists from Canada, Denmark, Norway, the United States, and the Union of Soviet Socialist Republics gathered in Fairbanks, Alaska, for the first international conference on the conservation of Polar Bears. The reports presented on this occasion demonstrated that relatively little accurate knowledge existed on the size and range of Polar Bear populations. The delegates agreed that conservation measures should be implemented immediately, pending the gathering of additional data by each nation, and that IUCN offices should be called upon to facilitate an exchange of information. Further meetings took place in 1967, 1968, 1970, and 1972, in the course of which the participating scientists organized themselves into the IUCN Polar Bear Specialist Group of the Survival Services Commission (now Species Survival Commission). Thus constituted, they negotiated the International Agreement on the Conservation of Polar Bears.[14] This international treaty was signed on 15 November 1973, ratified in 1976, and reaffirmed indefinitely in 1981. It remains in effect at the time of writing, with Ian Stirling of CWS sitting as one of the Canadian members of the permanent committee. In recent years, the perspective of the Polar Bear working meetings has been broadened significantly by the inclusion of Inuit participants from Alaska, Canada, and Greenland.[15]

Apart from the impetus that the Polar Bear Agreement gave to conservation and research, one of its primary values lies in the precedent that it set for environmental cooperation between circumpolar nations. Although compliance with its terms is purely voluntary on the part of the signatory governments, it stands as a meaningful example of how responsibility for the governance of wildlife can be assumed jointly by countries whose territories fall within the range of a vulnerable transboundary species.

While this exemplary compact for the protection of a single species was being developed among five northern countries, another treaty was under construction that would eventually bear signatures representing a sizeable majority of the world's nations.

CITES

Polar Bears were by no means the only victims of a growing demand for wildlife and wildlife products following the Second World War. The import and export of birds, other animals, and eggs, living or dead, were troubling to Canadian wildlife authorities on grounds that ranged from simple enforcement of game laws to the risk that exotic species might escape and become naturalized, to the detriment of native ones. As early as 1960, the 24th Wildlife Conference had recommended that:

> The Canadian Wildlife Service be requested to explore with federal legal authorities the possibility of a new federal act to provide control over:
>
> 1. The import into Canada of live animals, birds, or viable eggs without an import permit from the province of destination.
> 2. The interprovincial shipment of such animals, birds or eggs without an import permit from the

> province of destination, in addition to the export permit now required under the Game Export Act.[16]

At the same time, discussions were taking place in international wildlife circles, under the auspices of IUCN, about another threat posed to endangered species the world over. World trade was brisk, not only in exotic living creatures, but in ivory, rhinoceros horn, snake leather, and all manner of furs, feathers, and skins to adorn and amuse the rich and powerful. Various draft documents were circulated among nations during the 1960s with a view to developing the framework for an agreement. Eventually, detailed, formal negotiations took place in Washington from 12 February to 2 March 1973. The Canadian delegation included Nick Novakowski as the CWS representative. It was agreed that there should be a Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

A draft treaty was brought back to Ottawa for consideration, and John Heppes was seconded from Parks Canada to CWS to coordinate the administrative process of consultation with the provinces and territories whose approval would be required for Canadian ratification. Heppes's background made him an excellent choice for the assignment. A former wildlife official in the colonial administration of Uganda, he understood the needs and pressures not only from a Canadian perspective, but from that of developing nations as well.

Despite the fact that international trade in wildlife had been a topic of interest in Canada for more than a decade, it was no easy matter to secure agreement. As Heppes later recalled:

> The negotiations were quite interesting. Initially there was quite a lot of resistance from a number of the provinces who objected that we were interfering with their right to regulate wildlife. We had to convince them that what we were doing had nothing to do with their management of wildlife. The federal government was only doing what it had a clear right and responsibility to do, which was to regulate imports and exports. CITES does not apply internally to any country. If you choose, you can wipe out any CITES species within your own borders, so long as you don't try to export the products.[17]

Not least among the challenges he faced was the question of what legislative authority might enable Canada to enforce the provisions of the Convention. He had his own views on what would constitute the best solution:

> What I had really wanted was a CITES Act in which the articles of the Convention would have become the different items in the Act. The governing regulations could then have been made by our Minister for the specific purpose of governing the import and export of wildlife. That idea was shot down. Instead, we used the Export and Import Permits Act, which was first developed as legislation for the Department of Industry, Trade and Commerce and subsequently administered by the Department of External Affairs. If we were not to have a new Act, it was really the only appropriate piece of legislation in existence.[18]

Canada has played a leading role in protecting wetlands of international importance under the terms of the Ramsar Convention. On 22 October 1987, a plaque commemorating the selection of Cap Tourmente National Wildlife Area as Canada's first Ramsar site was unveiled by the Duke of Edinburgh (*second from left*) in the presence of (*l. to r.*) the Honourable Tom Macmillan (Minister of Environment), Arthur Irving (President, Ducks Unlimited Canada), Michel Côté (Member of Parliament), and the Honourable Clifford Lincoln (Minister of Environment, Quebec) (Photo credit: CWS).

Unfortunately, the international timetable allowed too little time to achieve a Canadian consensus on all the details pertaining to the draft treaty before a final round of negotiations settled on a definitive version of the Convention in February 1973.[19] The stated aim of the agreement was to control the exploitation of threatened or endangered species of plants and animals by controlling trade in the organisms themselves or in products made from them. For purposes of regulation and enforcement, it established three categories: Appendix I, listing species for which both an export permit from the country of origin and an import permit from the country of destination are required and for which no international trade for commercial purposes is allowed; Appendix II, including species that may be traded commercially but require a degree of monitoring, for which only an export permit is required; and Appendix III, within which individual countries may designate species inside their boundaries as requiring export permits, even if they are not controlled elsewhere. A

Conference of the Parties to the Convention would meet every two years to review performance and make amendments to the appendices.

It was remarkable that such a far-reaching and complex international agreement had been successfully concluded. As David Munro (now Director General, Liaison and Coordination Directorate, Environment Canada) remarked when inviting a constructive response from delegates to the 37th Wildlife Conference in July 1973:

> In the international field generally, nothing gets done except by [consensus] and free will. There is really no such thing as compulsion and I think that the fact that so many states have participated in this convention, and that 35 states have already signed it, indicates that there is quite a significant will in the international community to provide greater control over trade in endangered species and, by extension, to ensure the preservation of the species.[20]

It took another two years before the Department of External Affairs was able, in April 1975, to deposit the instruments of Canada's ratification of CITES with the Government of Switzerland in Berne, Switzerland. Thereafter, it would be Canada's obligation to live up to that commitment. Although authority for the Export and Import Permits Act rested with the Minister of External Affairs, CWS was designated as the scientific and administrative authority for the Convention. Nick Novakowski chaired the various scientific authorities until he retired in 1983, and John Heppes served as the CITES administrator until his retirement in 1991.

A large part of Heppes's work was educational. The agreement affected an enormous number of people: tourists returning to Canada with prohibited souvenirs; the clothing industry, which was accustomed to importing large quantities of furs, hides, and apparel made of wild materials; zoological and botanical gardens; and dealers in a variety of unusual items, ranging from exotic pets to alternative medicines. Heppes and his assistants — first Christina Sokulsky and later Bob McLean and Jean Robillard — conducted an energetic communications program, producing news releases, information brochures, and television announcements. They met with industry groups, from tourism and transportation to the Fur Fashion Council of Canada.

Starting in 1981, they also held training sessions for Canada Customs and RCMP enforcement officers. By March 1983, more than 80 seminars had been presented to about 800 participants. Given that the CITES appendices cover approximately 30 000 species of plants and animals, it would have been futile to attempt to make every officer an expert in identification. Instead, the training program aimed to provide enough knowledge that enforcement staff could readily recognize when items were questionable. Specialist advisors, often from museums or universities, were on call at all major ports of entry to confirm whether a given shipment was prohibited or qualified for entry without a permit.

In 1987, 12 years after Canada's ratification of CITES, the sixth meeting under the Conference of the Parties took place in Ottawa. It was a striking demonstration of how rapidly this cooperative international agreement had won worldwide support. The list of 35 original signatory countries in 1973 had grown to 95, of whom 84 sent delegations to the Ottawa conference. Another 21 nonsignatory states sent observers, as did 105 nongovernment organizations. Canada was well represented at the event. Not only was the Canadian delegation led by Tony Clarke, Director General of CWS, but the conference was chaired by David Munro.

Although the specific focus of CITES is restricted to trade regulations, its influence on wildlife governance has been much more inclusive. Within Canada, the need that the Convention created for agreement on what species were really endangered provided an immediate and positive rationale for the work of COSEWIC when it was created in 1977. Globally, CITES has underlined the concept that wildlife is not the property of one country or one organization but, rather, a universal resource. As this understanding has taken root, there have been major improvements in international cooperation on wildlife research and conservation. While it would be simplistic to argue that CITES was the direct forerunner of the Convention on Biological Diversity (1992), both are vitally important links in a chain of worldwide environmental initiatives that Canada has supported and promoted over the past 25 years, often through the involvement of CWS.

The Ramsar Convention

The Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971) is another example of a multilateral conservation agreement that has reinforced Canada's wildlife priorities. The idea of a treaty to promote the conservation of wetlands had originated in the 1960s with the International Waterfowl and Wetlands Research Bureau. Indeed, it was the International Waterfowl and Wetlands Research Bureau that organized the meeting of 18 nations and several international conservation organizations at the Iranian town of Ramsar, on the Caspian Sea, for which the agreement was named.

Prior to joining CWS in 1967 (see Chapter 3), Hugh Boyd had represented the United Kingdom on the International Waterfowl and Wetlands Research Bureau since 1956 and was one of the instigators of the idea of a global network of internationally significant wetlands. After coming to Canada, he maintained close contact with his former colleagues and worked steadily to promote Canadian participation in the plan.

With 9% of the world's renewable fresh water and a longer coastline than any other country in the

For more than 75 years, federal conservation officers like Andrew Rowsell, seen here setting out on his daily patrol from Baie-des-Loups in the summer of 1996, have guarded the isolated island seabird sanctuaries of the Lower North Shore, Quebec (Photo credit: CWS).

world, Canada was a natural candidate for involvement in the Ramsar Convention. Boyd's efforts were rewarded in 1981 when his adopted country acknowledged its vested interest in wetland survival and became the 29th nation to sign the pact. The Canadian decision, in turn, influenced the United States to add its support and laid a valuable foundation for further wetland conservation initiatives in Central and South America.

After the signing, it became a responsibility of CWS to secure Ramsar designation for suitable sites in Canada, in cooperation with provincial and territorial governments. The Wildlife Service responded vigorously to the opportunity. Between 1981 and 1988, some 30 wetland locations, many of them already identified as National Wildlife Areas or Migratory Bird Sanctuaries, were approved as Ramsar sites.[21] In the late 1980s, responsibility for meeting Canada's obligations under the Ramsar Convention was assigned to the Habitat Conservation Division of CWS. D. I. (Doug) Gillespie and, latterly, Clay Rubec played a leading role in this work, their efforts in the securement of new sites and the establishment and maintenance of a national Ramsar Network earning for CWS a high degree of international respect among wetlands managers.

With more designated wetland area (12.9 million hectares) than any other participating country, Canada was a logical country to host the triennial Ramsar meeting for 1987. The event, held in Regina, produced a fresh impetus to the work of the Convention and led to the election of Jim Patterson of CWS to chair the management committee of the International Waterfowl and Wetlands Research Bureau.

A more recent outgrowth of CWS participation in the international conservation of wetlands is the Western Hemisphere Shorebird Reserve Network. During the late 1970s, Guy Morrison and Ken Ross of CWS had made ornithological history with their aerial survey of shorebird wintering habitats around the perimeter of South America (see Chapter 3). Struck by the extreme dependence of shorebirds on key locations along their annual migratory circuit, Morrison conceived the idea of an international conservation initiative that would do for strategically important shorebird habitat what the Ramsar Convention does for waterfowl habitat. By the mid-1980s, the Western Hemisphere Shorebird Research Network had been established. George Finney, Regional Director of CWS (Atlantic Region), became a key supporter of this initiative, securing designation of the upper Bay of Fundy as a Western Hemisphere Shorebird Reserve Network site on the strength of its importance as a critically important feeding stop on the fall migration path of the Semipalmated Sandpiper.

Domestic Adjustments

While CWS was expanding its participation in wildlife protection and governance on the international front during the 1970s and 1980s, important changes were also occurring with regard to wildlife policy within Canada's borders. When the Canada Wildlife Act came into effect, on 27 July 1973, it constituted something of a high-water mark for federal leadership in the wildlife field in Canada. After more than 40 years during which the impetus and overview of the central government had steered Canada through the challenges of depression, war, and postwar recovery, there was a feeling abroad in the country that it was time for Ottawa to become more responsive to regional interests.

Initially, this tendency was reflected, at the federal level, in a readiness to regionalize the operations of many departments and agencies. Among them was CWS, which reorganized its operations to correspond with the five geographic regions of the Environmental Management Service of Environment Canada, effective April 1976. Over the next several years, it became clear that the impulse away from centralization would have a significant impact on more than the delivery of government services. It also manifested itself in a devolution of power. Political and philosophical debate focused on the idea of "participatory democracy" and questions of whether Canada was one nation, two nations, a confederation of equal partners, or perhaps a community of communities. After more than a generation during which national identity and common purpose had seemed secure, the 1970s ushered in a period of constitutional adjustment marked by an increasingly insistent assertion of provincial rights.

In the field of wildlife administration, notice of this transition to a more broad-based model of consultation was served by a report to the Federal–Provincial Wildlife Conference of 1973. Just two weeks before Royal assent was granted to the Canada Wildlife Act, a committee consisting of Alan Loughrey and Joe Bryant (CWS), J. Hatter (British Columbia), Gaston Moisan (Quebec), Al Murray (Manitoba), and K. Ronald presented a detailed review of the objectives, format, content, timing, and membership of the annual gathering. While affirming the ongoing value of the Conference, they addressed a number of key questions of governance that had been taken for granted for many years.[22]

One of these questions, the idea of rotating the chairmanship annually among the provincial delegates, has been noted above. Another was the observation that, with the recent formation of provincial and regional waterfowl technical committees, the role of the Conference in setting game bird hunting regulations under the Migratory Birds Convention Act was diminished. Increasingly, the review suggested, the primary importance of the conference would be as a forum for the sharing of information. It could facilitate communication between the provinces themselves, between the provinces and the federal government, and between both levels of government and a growing number of nongovernment organizations, such as Ducks Unlimited (Canada), the Canadian Wildlife Federation, the World Wildlife Fund (Canada), and the Canadian Nature Federation. Although the review group did not specifically recommend action on this, it did suggest that the establishment of a hierarchy of participation in the Conference itself be considered. They proposed four categories:

- Official voting delegates: one from each province and territory plus CWS.
- Participants: additional representatives from provincial game agencies, CWS, RCMP, etc.
- Official representatives: from interested nongovernment bodies (Ducks Unlimited, World Wildlife Fund, Canadian Nature Federation, etc.) and representatives of foreign governments.
- Guests: other participants, invited as required by the program content of a given year.

The following year, the format of the 38th Conference, in Victoria, British Columbia, was significantly altered to reflect the committee's suggestions for wider participation and a broader range of subject matter. Attendance, which for many years had averaged about 65, jumped to 100 participants, including an increased number of provincial and territorial staff and more delegates from nongovernment wildlife, natural history, and agricultural organizations. Content still included bread and butter items on waterfowl status and game bird hunting regulations, but the greater part of the program was devoted to more far-reaching questions: provincial views on compensation for wildlife damage; the ethics of hunting; urban wildlife; and the use of the social sciences in wildlife management. The 39th Conference, held in St. John's, Newfoundland, carried the trend further with a series of thematically linked workshops on the ecological, economic, and sociocultural values of wildlife, and how they might best be communicated.

Another indication of provincial readiness to take on a larger leadership role was the introduction, in 1975, of *Canadian Wildlife Administration*. This annual publication was produced on a rotating basis by the provinces and dedicated to reporting on the latest progress in wildlife administration by all the agencies participating in the Federal–Provincial Wildlife Conference.

The broadening of channels of discourse to encompass discussion of both the technical and the philosophical issues underlying wildlife policy did not simplify the task of governance or the achievement of consensus. Mention has been made elsewhere (see Chapter 6) of the fact that it took seven years to draft and negotiate a Canadian position on North American waterfowl management that had the unanimous consent of all the provinces and territories. This was by no means the only complex wildlife issue under consideration at the time.

In 1975, the James Bay and Northern Quebec Agreement was signed. It was the first modern "treaty" to be worked out with northern aboriginal people in Canada and acknowledged aboriginal control of hunting, trapping, and fishing in the area governed by the accord, including a spring goose hunt, which accounted for the country's largest take of migratory birds by aboriginal hunters. Because some of the provisions regarding hunting ran counter to the terms of the Migratory Birds Convention, the final wording of the Agreement committed the Canadian government to try to negotiate an amendment of the Convention with the United States.

The United States, meanwhile, had concluded a treaty with the Soviet Union, and this agreement, too, was in conflict. It authorized a subsistence take of birds in Alaska outside the seasonal limits imposed by the Convention. Both Canada and the United States were thus under some pressure to amend their long-standing migratory bird agreement as quickly as possible. The task of expediting this process fell to the federal wildlife agencies of the two countries.

In 1978, the United States Fish and Wildlife Service saw a chance to get an amendment approved by the United States Senate, but only if the terms could be agreed upon promptly. On the Canadian side, Hugh Boyd, then CWS Director of Migratory Birds, was set the task of guiding the legal drafting of a proposed amendment to the Migratory Birds Convention Act, assisted by Tony Keith, Director of Wildlife Research and Interpretation. To expedite matters on both sides of the border, it was decided that state and provincial governments would not be consulted on the amending language.

Reasonable though this approach may have been in terms of getting the job done quickly, it did not sit particularly well with provincial and territorial wildlife agencies in Canada. Recommendation Number 9 of the 43rd Federal–Provincial Wildlife Conference, held in Regina in June 1979, did not bode well for the amendment's chances of rapid approval:

> Whereas considerable time will be required to work out the implications of the recently signed amendment to the Migratory Birds Convention between Canada and the United States, and whereas the announcement of the amendment has stimulated public discussion and anticipation, particularly among native peoples:
>
> [Be it recommended] that the Canadian Wildlife Service take immediate steps to discuss with the provinces and territories the proposed changes in regulations under the Migratory Birds Convention Act that are necessary to implement the amendment.[23]

As it turned out, the attempt to amend the Convention was abandoned by the Americans because of anticipated resistance in the Senate and did not come to the table again until the 1990s.

Federal–provincial tensions may have handicapped progress at times, but they seldom succeeded in derailing important initiatives. As a rule, both CWS and the provincial and territorial wildlife agencies were far too deeply committed to the common purpose of sound governance to let their rivalries stand in the way of the real priority. They were too well aware that the financial resources available were scarcely adequate for the job, even with close cooperation. Thus, in 1980, the 44th Conference generated some very constructive discussion around the theme of "A National Policy on Wildlife." In the keynote address, David Munro, visiting Ottawa from IUCN headquarters in Switzerland, revisited the policy concepts and objectives that Bill Mair had presented to the Resources for Tomorrow Conference 19 years earlier.[24] CWS Director General Alan Loughrey tabled a draft federal policy document at the meeting,[25] and Tony Keith, as chair of the Steering Committee for a National Wildlife Policy, outlined the context for discussions of policy development both at the conference and subsequently. During the ensuing workshop sessions, most of the delegates participated constructively and welcomed the prospect of extensive further consultations over the coming year. Nonetheless, the assertiveness of the provinces was evident in comments like those of D. C. Surrendi, Manitoba's Assistant Deputy Minister of Natural Resources, who said:

> My minister, who spoke here the other day, made it very clear that no national policy will be imposed on the Province of Manitoba; that what we should be looking at is a framework of principles within which policies can be reflected or dealt with.[26]

CWS Director General Alan Loughrey responded with the reminder that:

> It was you[r] conference that asked the Program Committee to have a conference dealing with national policy which could be subscribed to by the provinces, by the NGOs [nongovernment organizations], and even by the feds. We are just trying to implement what you asked us to do last year, and if the national policy does not suit a province, or an agency, or an NGO, then I think they can say they do not adhere to it and why — no problem![27]

Surrendi's reply was that while they could all agree to national principles, he thought that "for the long-standing success of something of this nature and scale, perhaps the term 'policy' was a bit too strong." Such semantic nuances may explain why, when a statement of principles and actions was finally published in 1982, with the blessing of the Wildlife Conference and the approval of the Conference of Wildlife Ministers, it was not forthrightly labelled a wildlife policy for Canada but bore the self-consciously careful title *Guidelines for Wildlife Policy in Canada*.[28]

The guideline document had been prepared by the steering committee[29] with David Munro as the writer. The text was based on the issues defined at the 1980 Wildlife Conference and also drew on the 1980 World Conservation Strategy prepared at the IUCN under Munro's direction. The ecological approach central to that strategy was evident in the three stated goals of the Canadian document as well:

- To maintain the ecosystems upon which wildlife and people depend;
- To preserve the genetic diversity of wildlife;
- To ensure that the enjoyment and use of wildlife is sustainable.[30]

Six years later, when the 52nd Federal–Provincial Wildlife Conference met in Victoria, British Columbia, one of its central tasks was a revision of those policy guidelines. A number of innovations were introduced to the format of the Conference that year. The Wildlife Directors met in a private working session prior to the general conference, which was attended by more than 240 participants and guests. The papers, debates, workshops, and plenary sessions of the three-day forum constituted one of the most extensive public discussions of wildlife policy in the history of Canada.[31] The recommendations that emerged from it were referred to a task force[32] chaired by Tony Keith, which drew on them to draft a new policy document. The final statement was adopted by the Wildlife Ministers' Council of Canada in September 1990 and published in 1992 by CWS, this time with the unapologetic title *A Wildlife Policy for Canada*.[33] The document, longer and more comprehensive than its predecessor, retained similar overall goals but addressed them in greater detail under the headings:

- Expanding the scope of wildlife policy;
- Providing for wildlife in economic and environmental policies;
- Involvement of aboriginal peoples in wildlife management;
- Improving wildlife conservation;
- Involving the public;
- Implementation.

The following excerpt from the Introduction illustrates the extent to which the perception of wildlife governance had changed since 1947:

> Recently, public concern for wildlife has expanded to embrace the variety of life in all its forms. And the World Commission on Environment and Development has made it clear that conserving ecosystems and the diversity of their species is a prerequisite for sustainable development. Thus, wildlife in this policy refers to all wild organisms and their habitats — including wild plants, invertebrates, and microorganisms, as well as fishes, amphibians, reptiles, and the birds and mammals traditionally regarded as wildlife.
>
> This broader perspective provides for guidance on the many species of wild organisms not covered by existing policies and supports an ecosystem approach to conservation. Wild species are managed by a number of agencies, including those responsible for terrestrial animals, fishes, marine mammals, and trees. These resource sectors have their own legislation and policies. The *Wildlife Policy for Canada* is intended to complement them, so that there may be a comprehensive set of policies guiding the management of Canada's flora and fauna. Thus, agencies and organizations responsible for freshwater, marine, or terrestrial resources are expected to extend their concern to conserving the biodiversity of the ecosystems involved.
>
> This national policy is not intended to alter the division of roles and responsibilities between federal and provincial or territorial governments.
>
> Implementation of *A Wildlife Policy for Canada* requires the leadership of federal, provincial, and territorial governments, and the effective participation of aboriginal groups, nongovernmental organizations (including corporations and educational institutions), and the general public. This partnership, deploying the skills and resources of all participants, will help to secure wildlife, optimize its benefits, and enhance the quality of life for all Canadians.[34]

Changes in the Nineties

In the wake of this policy, a new flurry of initiatives was launched to improve wildlife governance in Canada. The federal government's Green Plan led the way, in December 1990. For the first time in several years, CWS was able to access new money to accelerate important programs, such as NAWMP, research and conservation of nongame birds, enhancement of the toxic chemicals program, and the creation of wildlife research chairs at universities in British Columbia, New Brunswick, Nova Scotia, and Newfoundland and Labrador.

In 1991, the Minister of the Environment announced a national wildlife strategy and an interim policy respecting application of the Migratory Birds Convention Act to closed-season hunting and egg gathering by aboriginal people.[35] The statement marked the resumption of efforts to negotiate amendments to the Migratory Birds Convention (see also Chapter 2).

Having met with disappointment on this issue a decade earlier, neither Canada nor the United States was inclined to take chances this time. From 1992 to 1995, a painstaking process of consultation took place. Involving a wide variety of federal, provincial, and state agencies, native groups, and nongovernment environmental advocacy organizations, it was led by Greg Thompson, Director of the Migratory Birds Branch, and overseen by Director General David Brackett.

Negotiations between the United States and Canada were successfully completed on 27 April 1995, at Parksville, British Columbia, where a protocol to amend the Migratory Birds Convention was initialled by the chief negotiators for both countries. David Brackett, who had played a crucial role throughout the long process, including the negotiations, was jubilant. The document outlined several key amendments. It accommodated the traditional harvest of migratory birds by aboriginal peoples in northern regions. It permitted qualified residents of northern Canada to take migratory game and nongame birds as part of a subsistence lifestyle. It allowed for an early fall hunting season for residents of Yukon and the Northwest Territories. It authorized Canada to regulate the harvest of murres in the Province of Newfoundland and Labrador. It increased the involvement of aboriginal peoples in the study and management of migratory bird populations.[36]

The importance of the amendments was more far-reaching than might be suggested by these specific modifications. Failure to bring the treaty into conformity with current practices and laws could have led to its abrogation, ending 80 years of international cooperation between Canada and the United States in the field of wildlife conservation and protection. Historically, the status of the Migratory Birds Convention as an international agreement has been offered as a fundamental justification for the federal government's involvement in the management of migratory birds. It might be argued that the demise of the Convention would erode the legal basis of this arrangement, leaving the entire responsibility for the protection of migratory birds to revert to the provinces.

Fortunately, these hypotheses were not put to the test. In anticipation of agreement on the amending protocol, Parliament amended Canada's Migratory Birds Convention Act in May 1994. With the legislative framework already in place, the federal Cabinet was able to grant rapid approval of the Parksville protocol. The protocol was formally signed on 14 December 1995 by the Honourable Sheila Copps, Minister of the Environment, on behalf of Canada, and by Bruce Babbit, Secretary of the Interior, on behalf of the United States. In Washington, President Clinton forwarded the agreement to the Senate on 20 August 1996, where it received approval on 23 October 1997. At the time of writing, only the formality of an official declaration, anticipated before the end of 1998, was required to put the amended Convention into effect.

A complementary step towards continental cooperation in wildlife management at this time was the development of a tripartite agreement for the conservation of migratory birds and their habitats in Mexico. Following the establishment of NAWMP (see Chapter 6), Tony Clarke and his counterpart, Frank Dunkle of the United States Fish and Wildlife Service, visited Mexico to invite that country's participation. While the Mexican authorities were not prepared to join NAWMP at that point, they were ready for a less formal framework of collaboration. When David Brackett succeeded Clarke as Director General of CWS, he proposed that the long-standing Canada–USA and USA–Mexico wildlife committees be dissolved and replaced with one body representing all three countries. Steve Wendt, CWS scientific authority for NAWMP since 1989, was assigned the task of working with his counterparts in the other wildlife agencies to develop a functioning model. The result was the Canada–USA–Mexico Trilateral Committee for Wildlife and Ecosystems Conservation and Management, which held its first official meeting in 1996.

Meanwhile, a rapid-fire series of other developments, both international and domestic, were reshaping the governance of wildlife in Canada. June 1992 saw CWS staff involved in providing background support services for the Earth Summit in Rio de Janeiro, Brazil. In December of that year, Canada signed the Convention on Biological Diversity. At about the same time, federal and provincial ministers responsible for parks, wildlife, and environment announced their determination to complete a national network of protected areas representing all the natural regions of Canada and to take steps to protect critical wildlife habitat.

Another long-standing issue was addressed in December 1992, when the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act received Royal assent (see Chapter 2). Nearly 20 years after John Heppes's appointment as CITES Administrator, an Act was in place that was specifically devoted to implementing Canada's obligations under CITES. It replaced the existing Game Export Act and ended dependency on the Export and Import Permits Act for authority to control illegal trade in wildlife.

Wildlife was afforded additional legislative support in June 1994, with amendments to the Canada Wildlife Act and to the Migratory Birds Convention Act (see above). In particular, the changes focused on greater protection of habitat and species, as well as steps to strengthen enforcement of regulations and the provisions of stiffer penalties for violators on conviction (see Chapter 2).

Progress towards the implementation of the Convention on Biological Diversity led to publication, in November 1994, of *Biodiversity in Canada: A Science Assessment*,[37] drawn up by a team led by Tony Keith. This document served as a foundation for articulation of the Canadian Biodiversity Strategy in 1995.

Recognizing that neither COSEWIC nor the RENEW program (see Chapter 9) provided enforceable protection for endangered species, the federal government released a paper in 1995 entitled *The Canadian Endangered Species Protection Act: A Legislative Proposal*. CWS played a major role in organizing and coordinating a series of public consultations in provincial capitals across the country. The resulting feedback revealed a wide range of opinions from provincial governments, research and teaching institutions, corporations, and nongovernment organizations. The influence of these views was reflected in a revised version of the proposed legislation, which was tabled in the House of Commons but failed to pass before the dissolution of Parliament for the general election of 1997.

Through all these legislative, regulatory, and consultative changes, CWS itself was subjected to the stress of unprecedented redefinition. A major departmental restructuring of Environment Canada in 1993 saw CWS functions integrated within the Environmental Conservation Service. For a time it appeared that the identity of CWS itself might vanish in the larger administrative scheme of things. Central, coordinating functions surrounding the office of the Director General still officially bore the name of the agency that had, for more than 40 years, been a world leader in wildlife research, conservation, and interpretation. Elsewhere, even the use of the title Canadian Wildlife Service varied from region to region.

The long-standing series of annual Federal–Provincial/Territorial Wildlife Conferences underwent redefinition as well. After 1989, these national gatherings continued, but at a scale greatly diminished from that of their heyday in the 1970s and 1980s. Although they still take place, they have reverted to an earlier format consisting of an annual closed meeting of federal and provincial/territorial wildlife directors, followed by a modest get-together with nongovernment organizations to exchange information. One reason for the change may have been the reluctance of provincial/territorial wildlife officials to defend to their ministers some of the resolutions passed by the conferences. Another may have been the proliferation of other formal ways for directors and nongovernment organizations to discuss important issues. Habitat, for example, became less of a preoccupation because of the existence of Wildlife Habitat Canada, whose board has included provincial directors. Endangered species issues are discussed by the board of RENEW. Wetlands conservation is dealt with at meetings of the North American Wetlands Conservation Council (Canada) or of Habitat Joint Venture boards. Wildlife disease issues are now discussed at meetings of the board of directors of the Canadian Cooperative Wildlife Health Centre with the deans of the veterinary colleges.

At the time of writing, the organizational and administrative mutations of the 1990s are far too recent for the verdict of history to be rendered upon them. Clearly, though, Canada's need for an effective, responsive, science-based, national wildlife agency remains as strong as ever. Throughout the 50th anniversary of CWS in 1997, the enthusiasm of the celebrants and the outpouring of public appreciation attested to the vitality of that need.

Notes

1. John Macoun, *The Forests of Canada and their Distribution, with Notes on the More Interesting Species* (Ottawa: Transactions of the Royal Society of Canada, Section IV, 1894).
2. Gordon Hewitt, *The Need for a Nation-wide Effort in Wild Life Conservation*, National Conference, 18–19 February 1919, Report 8-16, as quoted in Janet Foster, *Working for Wildlife: The Beginning of Preservation in Canada* (Toronto: University of Toronto Press, 1971), page 202.
3. Harrison F. Lewis, *Lively: A History of the Canadian Wildlife Service* (Canadian Wildlife Service Archive, File Number CWSC 2018, unpublished manuscript, 1975), pages 188 and 202.
4. Department of Northern Affairs and National Resources, *Minutes of the 18th Federal–Provincial Wildlife Conference* (Ottawa: National Parks Branch, 1954), page 34.
5. David A. Munro, personal communication, interviewed at Sidney, British Columbia, 30 November 1996.
6. Department of Northern Affairs and National Resources, *Minutes of the 22nd Federal–Provincial Wildlife Conference* (Ottawa: National Parks Branch, 1958), page 30.
7. Munro, personal communication. (See note 5)
8. David Munro, "Legislative and administrative limitations on wildlife management" in *Resources for Tomorrow: Conference Background Papers, Volume 2* (Ottawa: Department of Northern Affairs and National Resources, 1961), pages 868–880.
9. W. W. Mair, "Elements of a wildlife policy" in *Resources for Tomorrow: Conference Background Papers, Volume 2* (Ottawa: Department of Northern Affairs and National Resources, 1961), pages 931–935.
10. Honourable Arthur Laing, "What price wildlife?" (text of a speech given in Banff, Alberta, to the Alberta Fish and Game Association, as released to the national media at 7 p.m. (MST) 5 February 1966).
11. J. Anthony Keith, personal communication, interviewed at Ottawa, 2 November 1997.
12. A. G. Loughrey, "Research and conservation authorized by the Canada Wildlife Act," memorandum to Assistant Deputy Minister, Environmental Management Service, dated 18 November 1977 (Hull, Quebec: National Wildlife Research Centre files, 1977).
13. Ian Stirling, *Polar Bears* (Ann Arbor, Michigan: University of Michigan Press, 1988).
14. Stirling, *Polar Bears*. (See note 13)
15. Øystein Wiig, Erik W. Born, and Gerald W. Garner, *Polar Bears: Proceedings of the Eleventh Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 25–27 January 1993, Copenhagen, Denmark* (Gland, Switzerland: International Union for the Conservation of Nature and Natural Resources, 1995).
16. Recommendation Number 3 in *Minutes of the 24th Federal–Provincial Wildlife Conference, 16–17 June 1960*, Ottawa (Ottawa: Department of Northern Affairs and National Resources, National Parks Branch, 1960), page 44.
17. John Heppes, personal communication, telephone interview, 21 November 1997.
18. Heppes, personal communication. (See note 17)
19. D. A. Munro, "Introductory remarks" in *Transactions of the 37th Federal–Provincial Wildlife Conference, 9–12 July 1973*, Ottawa (Ottawa: Environment Canada, Canadian Wildlife Service, 1973), pages 28–29.
20. Munro, "Introductory remarks," page 29. (See note 19)
21. D. I. Gillespie, H. Boyd, and P. Logan, *Wetlands for the World: Canada's Ramsar Sites* (Ottawa: Environment Canada, Canadian Wildlife Service, 1991).
22. A. G. Loughrey, J. Bryant, J. Hatter, G. Moisan, A. Murray, and K. Ronald, "Report of the committee to re-examine the Federal–Provincial Wildlife Conference" in *Transactions of the 37th Federal–Provincial Wildlife*

Conference, 9–12 July 1973, Ottawa (Ottawa: Environment Canada, Canadian Wildlife Service, 1973), pages 62–65.

23. Recommendation Number 9 in *Transactions of the 43rd Federal–Provincial Wildlife Conference, 26–29 June 1979*, Regina (Ottawa: Canadian Wildlife Service, 1979), page 240.
24. D. A. Munro, "Wildlife policy as a contribution to national development" in *Transactions of the 44th Federal–Provincial Wildlife Conference, 24–27 June 1980*, Ottawa (Ottawa: Canadian Wildlife Service, 1980), pages 62–73.
25. A. G. Loughrey, "A draft federal wildlife policy for Canada" in *Transactions of the 44th Federal–Provincial Wildlife Conference, 24–27 June 1980*, Ottawa (Ottawa: Canadian Wildlife Service, 1980), pages 32–36.
26. Quoted in *Transactions of the 44th Federal–Provincial Wildlife Conference, 24–27 June 1980, Ottawa* (Ottawa: Canadian Wildlife Service, 1980), page 136.
27. Quoted in *Transactions of the 44th Federal–Provincial Wildlife Conference.* (See note 26)
28. Minister of the Environment, *Guidelines for Wildlife Policy in Canada* (Ottawa: Minister of Supply and Services, 1983).
29. Members of the steering committee were K A. Brynaert, J. A. Keith, D. J. Neave, J. D. Roseborough, and L. Whistance-Smith.
30. Minister of the Environment, *Guidelines*, page 6. (See note 28)
31. *Transactions of the 52nd Federal–Provincial/Territorial Wildlife Conference, 14–17 June 1988, Victoria* (Ottawa: Canadian Wildlife Service, 1988).
32. In addition to chairman J. A. Keith, the membership of the task force included R. Andrews, T. Beck, G. Blundell, J. Cinq-Mars, P. Gray, P. Griss, S. Hazell, D. Neave, R. Prescott-Allen (writer), and A. Smith.
33. Wildlife Ministers' Council of Canada, *A Wildlife Policy for Canada* (Ottawa: Canadian Wildlife Service, 1992).
34. Wildlife Ministers' Council of Canada, *A Wildlife Policy*, pages 6–7. (See note 33)
35. Minister of the Environment, *Interim Policy on Application of the Migratory Birds Convention Act and the Canada Wildlife Act Respecting Closed-season Hunting and Egging by Aboriginal People* (Ottawa: Environment Canada, Canadian Wildlife Service, 1991).
36. Environment Canada, Background briefing note (Ottawa: Environmental Conservation Service, 1995).
37. Biodiversity Science Assessment Team, *Biodiversity in Canada: A Science Assessment for Environment Canada* (Ottawa: Environment Canada, 1994).

1992–1997: The Challenges of Change

The mid-1990s were a period of contrasts for CWS. On the positive side, many long-standing Wildlife Service priorities were coming to fruition. NAWMP was well and truly launched, with Joint Ventures securing unprecedented areas of habitat for conservation across the country (see Chapter 6). Amendments to both the Canada Wildlife Act and the Migratory Birds Convention Act and passage of the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act had not only strengthened CWS's legislative capabilities (see Chapter 2) but, taken together, amounted to the most complete overhaul of Canadian wildlife laws ever undertaken. There were encouraging indications, especially after the signing of the Parksville Protocol in 1995, that amendments to the Migratory Birds Convention itself would soon be achieved (see Chapter 10). With the announcement of substantial funding for Canada's National Wildlife Strategy under the Green Plan, hopes were high that constructive partnerships would restore to research and conservation activities much of the vitality that had been lost during and after the debacle of 1984.

Nationally and internationally, awareness of ecological challenges was generating widespread public support for the kind of results-oriented new initiatives that CWS could deliver. David Brackett had joined CWS as Director General in 1991, just as the agency was gearing up to participate in the United Nations Conference on Environment and Development in Rio de Janeiro. He was deeply mindful of the fact that Canada's signing of the Convention on Biological Diversity created new responsibilities for Canadian wildlife administrators. Soon after his arrival, he had supported establishment of the Biodiversity Convention Office within CWS.

Charged with leading national efforts to define Canada's response to the Convention, the Biodiversity Convention Office under John Herity concentrated largely on the coordination of policy, operating through a network of contacts within and outside of government. At the federal level, it was instrumental in ensuring that the Interdepartmental Committee on Biodiversity became a forum for exchanging ideas and advice on strategies and actions. A Federal/Provincial/Territorial Working Group was set up to perform a similar function in an intergovernmental setting, whereas the Canadian Biodiversity Forum accommodated the need for input from a wide range of other interested stakeholders.

From November 1992 to November 1994, the main focus of Biodiversity Convention Office activity was the articulation of the Canadian Biodiversity Strategy. This document, developed in partnership with federal, provincial, territorial, and nongovernment interests, encompassed the full range of Canada's obligations under the Convention. Under the title *Canada's Biodiversity: A Commitment to Its Conservation and Sustainable Use*, it was signed in 1995 by the federal Minister of Environment and by provincial ministers responsible for the conservation of biodiversity. On an international scale, the Biodiversity Convention Office worked to ensure global implementation of the Convention, participating in policy discussions and paving the way for Canada's selection, in 1995, as host country for the Convention Secretariat.

Like his predecessor Tony Clarke, Brackett was a dedicated promoter of partnerships as a means of extending the influence and effectiveness of CWS. As Director General, he chaired the Canadian Wildlife Directors' Committee, which had more or less taken the place of the Federal–Provincial/Territorial Wildlife Conferences since 1990. At various times, he also chaired the Wetlands Council of NAWMP and RENEW, acted as a board member of Wildlife Habitat Canada and IUCN, was Canadian representative to CITES, and cochaired the Trilateral Committee dealing with conservation concerns held in common by Canada, the United States, and Mexico.

Another response to the public temper of the times with regard to wildlife was the contribution of CWS to the issue of humane trapping, especially in the persons of Nick Novakowski in earlier years and of Neal Jotham later on. Public concern about methods of trapping fur-bearing mammals — particularly the use of leghold traps — dated back as far as the late 1940s. From time to time, there were demands, both in Canada and abroad, for the abolition of the fur trapping industry. Although it was unlikely that an activity that generated up to $600 million for the gross national product and employed about 100 000 people would be shut down, there had been a growing sense through the 1960s and 1970s that practices that caused needless suffering to animals must be mitigated. CWS had hired Jotham in 1984 for the express purpose of coordinating efforts in that direction.

As publics around the world became sensitized to the issue, the intensity of protests grew to such an extent that, by the 1990s, the European Union had approved a regulation that would have banned the importation of wild fur from any country that had not banned the use of jaw-type leghold traps or that did not use internationally agreed humane standards of trapping. At the suggestion of Canada, work began on the development of an International Organization for Standardization (ISO) trapping standard. CWS helped fund the initiative, and an ISO technical committee chaired by Neal Jotham developed a standard for trap testing that won approval in 1997. At the same time, Jotham was deeply involved in negotiating an Agreement on International Humane Trapping Standards between Canada, the European Union, and Russia. Reviled at times by animal rights activists and hunting/trapping organizations as well, he maintained a good-humoured credibility and tenacity that helped bring those negotiations to a successful conclusion in 1997.

Perhaps it was thanks to the possession of similar qualities that two women attained senior management positions within CWS during this period. Although women had worked as directors for short periods previously, Lynda Maltby at headquarters and Isabelle Ringuet in the Quebec Region were the first female employees to rise through the ranks and assume full-time leadership positions at the senior management table.

On the negative side of the ledger, a protracted economic recession and a burgeoning federal deficit at the outset of this period had set the stage for five years of deep cutbacks in the financial and human resources allotted to federal departments and agencies. Driven by a political commitment to eliminate the deficit, the government introduced an across-the-board Program Review exercise aimed at optimizing the efficiency and affordability of programs and ensuring that federal funds were being spent on federal responsibilities. The fiscal target for Environment Canada was a 39% reduction in the departmental budget within three years, from 1994–1995 to 1997–1998. Inevitably, CWS was affected.

Planning for the reductions actually began in 1993, hard on the heels of a major reorganization that virtually eliminated the institutional identity of the Wildlife Service. The restructuring reinforced the matrix management system that had been in place to a greater or lesser degree since the late 1970s, combining all components of the department within each region under a single Regional Director General who reported directly to the Deputy Minister of Environment in Ottawa. This resulted in a further organizational distancing of regional wildlife operations from CWS headquarters. The Director General of CWS no longer sat at the same management table with the regional directors, who, as Regional Directors of Environmental Conservation, no longer had even a reference to wildlife in their titles. In addition, the enforcement activities of CWS were now merged with those of Environmental Protection, except in the Atlantic and Ontario regions (see Chapter 2).

At headquarters, David Brackett outlined a new, three-branch structure for CWS[1] in February 1994: Wildlife Conservation, under Steve Curtis; Water and Habitat Conservation, under Jim McCuaig; and the National Wildlife Research Centre, under Tony Keith. The Biodiversity Convention Office was shifted, for a short time, to a separate Biodiversity Directorate, from which it returned to CWS in 1995.

When the Program Review budget cuts were actually applied, starting in 1995, the wildlife sector of

The evolution of responsibilities from a narrow focus on migratory birds to something much broader is evident in CWS's leadership on international biodiversity issues. David Brackett (*r.*) heads the Canadian delegation, including John Herity (*l.*), at the Fourth Meeting of the Conference of the Parties to the Convention on Biological Diversity in Bratislava, Slovakia (Photo credit: I. Dubovsky).

the federal government was thus already under stress. Some cuts simply terminated activities, such as the Peregrine Falcon breeding and rearing project at Wainwright, Alberta (see Chapter 9), that were already on the verge of completion. Others struck more deeply at ongoing programs. Work on endangered wildlife species that were not directly under federal jurisdiction was dropped. A plan to construct a new aviary at the National Wildlife Research Centre was cut. Throughout the Wildlife Service, routine duties and functions had to be sustained at acceptable levels of performance with fewer resources.

Cumulative cuts to CWS programs between 1994 and 1997 amounted to $9.5 million (24%) and 64 full-time positions (18%). Compared with the target reduction of 39% that had been set for the department as a whole, CWS might be thought to have fared relatively well. However, the small size of the agency, its uncertain status in the wake of restructuring, and the cumulative resource reductions of the previous 12 years intensified the impact of the Program Review, resulting in a disproportionate loss of scientific, technical, and policy expertise to the cause of wildlife conservation in Canada.

One of the greatest challenges stemmed from the fact that, during the planning stages, the Program Review process was shrouded by Cabinet secrecy. CWS officials were prohibited from discussing problems and possibilities with their colleagues in other organizations. As a result, many provincial/territorial and nongovernment partners of CWS became frustrated by both the real loss of funding and the apparent loss of trust. Selected partnerships under the Green Plan were sharply reduced or even eliminated. For example, funding for the Cooperative Wildlife Ecology Research Network was cut from $1 million a year to $350 000, with the result that, of the five regional programs originally envisaged, only two ever came to pass.

The reductions, both in core science work and in support for cooperative partnerships, came at the same time that increasing concerns about loss of biodiversity were putting additional pressure on CWS and its partners to respond constructively. At the 1993 meeting of Canadian wildlife directors in the Yukon, David Brackett had proposed that the RENEW program for the recovery of endangered species (see Chapter 9) be adjusted within existing constitutional authorities. In supposing that the matter could be handled on an administrative level, he later acknowledged, he underestimated the degree of interest that the public, politicians, and nongovernment organizations would take in the issue. By 1994, it was evident that the endangered species file was becoming a defining feature of his life. Outside of CWS, it produced an unprecedented groundswell of wildlife advocacy. An Endangered Species Coalition was formed with a single focus — the enactment of legislation. The ensuing process led eventually to development of the National Accord for the Protection of Wildlife Species at Risk in Canada, approved by the Wildlife Ministers' Council in 1996, and to the drafting of a Canada Endangered Species Protection Act (see Chapters 9 and 10), which would likely have received Parliamentary approval had the general election of 1997 not intervened.

In the annals of CWS, however, 1997 stood for much more than a thwarted legislative initiative. It marked the 50th anniversary of the Wildlife Service, and, despite the concerns and frustrations of recent years, members of the agency family seized on the occasion to affirm their personal and professional dedication to the belief that stewardship of wildlife is an important value of Canadian culture and society.

The affirmation took many forms. The public attended wildlife-related events, open houses, and demonstrations at regional offices and National Wildlife Areas. A 50th anniversary logo, featuring the well-known CWS loon, found its way onto a remarkable variety of surfaces, from special publications and departmental stationery to sweatshirts and baseball caps. A sign of the times was the appearance on the Internet of a CWS website. For the first time, descriptions of CWS programs, activities, and publications, including the popular *Hinterland Who's Who* series, could be accessed from home computers across Canada.[2] A feature of the website during 1997 was a guest book in which well-wishers were invited to inscribe electronic greetings, and hundreds, ranging from school children to the Prime Minister, did just that.

On Saturday, 1 November 1997, CWS staff members and friends, past and present, gathered at a community centre overlooking the Ottawa River for a birthday celebration. Wildlife Service pioneers — Joe Bryant, Graham Cooch, Nick Novakowski, John Tener, Alan Loughrey, Vic Solman — were honoured by the ovations of the crowd. Poster displays of photographs chronicled highlights of the preceding half century. Yet, though the atmosphere was imbued with nostalgia for the "good old days," a more important element was the sense of camaraderie that animated the occasion. This was no wake for past glories, but a collective avowal that the accomplishments of the first 50 years should serve as inspiration for present endeavours and as a prologue for adventures yet to come.

Notes

1. D. Brackett, memorandum to all Canadian Wildlife Service staff, dated 8 February 1994.
2. The URL is www.ec.gc.ca/cws-scf.

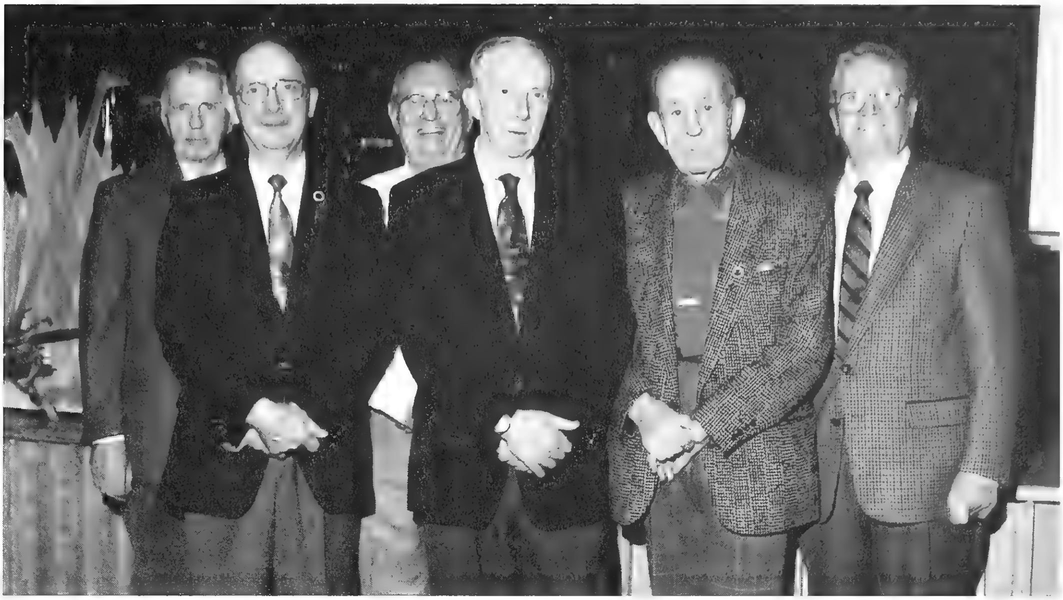
Epilogue: CWS — A Work Still in Progress

Half a century ago, Harrison Lewis took charge of Canada's newly created Wildlife Service. Since then, the agency has probably accomplished more on behalf of wildlife than he ever imagined possible and certainly far more than can be incorporated in the pages of this history. Indeed, to do full justice to the scientific enquiries of CWS, its administrative accomplishments, and its role in the evolution of wildlife policy in Canada, not to mention the wealth of anecdotes and tall tales that have accumulated within its collective memory, would require several volumes. The present, preliminary sketch has had more modest goals: to outline the broad themes and activities of CWS to date and to capture, in a few, highlighted examples, the passion to comprehend and conserve wildlife that has motivated most, if not all, of the men and women who have worked there.

Recognition of that passionate commitment is central to an understanding of the CWS story. Anyone who knows the Wildlife Service knows that it differs greatly from typical bureaucratic organizations in either the public or the private sector. Competence, integrity, and courteous, efficient service are attributes one hopes to encounter with regularity, whether in a government office, a bank, or a fast food restaurant. One does not anticipate the kind of dedication that motivates individuals to endure isolation, discomfort, and physical risk to life and limb, sometimes for weeks and months on end, in order to expand our collective knowledge of the biodiversity and safeguard the ecological well-being of the land we call home.

The chronicles of CWS are filled with examples of a level of professional commitment so far beyond the call of duty that it can only be attributed to the zeal of personal vocation. Some of those examples have, with the passage of years, acquired an almost mythic stature. Ernie Kuyt's 30-year crusade to preserve the Whooping Crane has been told and retold until the great white bird has become an icon of the campaign to save endangered species around the world. The essential point is that his remarkable devotion to that cause is by no means unique in the culture of the Wildlife Service. On the contrary, it is more nearly typical of the dedication that has been shown by CWS personnel in every part of the country over the past 50 years.

Some accomplishments, notably those that have contributed to the survival of beautiful and imposing wildlife species in spectacular wilderness landscapes, have stirred the public imagination readily. The less obviously appealing work — sampling invertebrates in the muck of a prairie slough, probing fecal samples for evidence of intestinal parasites, or performing a lab analysis to establish the source of



Some of the pioneers of CWS research assembled in Ottawa on 1 November 1997 to celebrate the 50th anniversary of CWS with hundreds of more recent employees: (*l. to r.*) John Tener, Joe Bryant, Graham Cooch, Alan Loughrey, Vic Solman, Nick Novakowski (Photo credit: Jim Haskill).

crude oil fouling a seabird's wing — is no less important or challenging. An essential role in this work has been played by technicians — people like Dennis Andriashek, Bill Barrow, Barb Campbell, Garry Gentle, Randy Hicks, Paul Madore, Norm North, Gaston Tessier, and dozens of others — who have contributed enormously to CWS field operations, working on habitat development and maintenance, assisting in field research and demonstration projects, finding practical solutions to unexpected problems, participating in the conduct of surveys and wing bees, and in their lives demonstrating the value of conservation to their communities. They have been full-fledged members of the scientific team. Likewise, enforcement coordinators, combining sound police work with a keen interest in public education and the development of meaningful regulations, have played an important role.

Biologists and chemists, research scientists and technicians, enforcement coordinators and interpreters have been specifically acknowledged in this history. One group that has not had adequate recognition includes the many financial and administrative workers who, over the years, have done their utmost to ensure that the paperwork and procedures common to government agencies should stand not in the way of, but in service to, the mission of CWS. That mission was, in many ways, alien to the conventions of bureaucracy. Those clerks and administrators, who managed to arrange the purchase of station wagons in the 1940s, at a time when such practical machines were not on the list of approved vehicles for government use, were unusually flexible and innovative. In the orderly halls of Ottawa, it took courage to insist that the lowest bidder might not necessarily supply the best or safest means of flying to remote wilderness field camps.

A good case in point is Doug Pollock, a lifelong administrator who knew the rules, but knew with equal certainty that his first job was to facilitate the work of CWS. His particular talents placed him at the centre of complex financing arrangements for programs such as Wildlife Habitat Canada. He grew to be much more than an administrator, playing a key role in promoting CWS involvement in humane trapping, taking a leading role in CITES, and smoothing relations with provincial wildlife officials. For years, he worked tirelessly to ensure that the deliberations of the Federal–Provincial Wildlife Conferences were backed by a competent secretariat that could guarantee appropriate follow-up on commitments and recommendations.

A great many other people in support roles have grown significantly in their jobs in order to meet unforeseen needs: the clerk who became a website technician; numerous secretaries or stenographers who became program administrators; the editor who became an author. From 1947 to the present, intense loyalty to the agency and its mission has been a hallmark of the staff, regardless of rank or job description. Indeed, longevity of service among support staff has been as remarkable as that of the many biologists and researchers who have chosen to spend all or most of their career with CWS. A job with the Wildlife Service has been the ultimate career goal for many young Canadians, and a dream that hundreds of them have realized. Once hired, most seem to have readily adopted as their motto James Harkin's injunction to Harrison Lewis on the occasion of his appointment in 1920: "Now remember. You are on duty twenty-four hours a day — and twenty-five if we need you!"

That attitude explains, perhaps, why someone like Steve Wendt or Gaston Tessier might feel it was appropriate, on his own time and at his own expense, to learn Spanish in order to improve his ability to communicate with wildlife biologists and administrators in Latin America. Or why Kathy Dickson and Steve Wendt took it upon themselves to learn sign language so they could communicate natural history to hearing-impaired audiences. Or why Jean Gauthier and Yves Aubry spent 10 years of their professional and personal lives coordinating the work of a thousand volunteers to gather the data for, write, edit, and publish the monumental *Atlas of the Breeding Birds of Southern Quebec*.[1] Or why dozens of CWS personnel across Canada spend weekends and vacation time participating in Christmas Bird Counts and Breeding Bird Surveys, supervising educational displays at shopping malls during National Wildlife Week, working as volunteers with community youth activities, and volunteering as members of conservation organizations.

The context and the content of CWS work have changed markedly since 1947. The focus has broadened from a concentration on selected species to habitat conservation and to the preservation of biodiversity. At the outset, little was known about the life history of many of the mammals, birds, and fish for which CWS was responsible. The years of inventories and field observation produced a foundation of knowledge on which more sophisticated studies in population dynamics and ecological assessment have since been built.

The evolution of technologies has hastened the process of change. Dewey Soper, Alan Loughrey, and other veterans of the early years did significant amounts of their travel by dog team or canoe. Small wonder that a single field season could consume months. Today, research crews are flown to remote study areas by Twin Otter. They move from site to site by helicopter. They check their office voice mail via satellite telephone links. An entire field trip may now be completed in as little as two or three weeks, of which travel is the least time-consuming factor.

Satellite technology has revolutionized other aspects of CWS work, as well. A generation ago, for example, habitat assessment and mapping were largely ground-based activities. Now, remote sensing enables people like Andy Didiuk, in Saskatoon, to develop maps of wildlife habitat all across the country, including detailed information on terrain and vegetative cover. Satellite photographs provide the bulk of the information, which is subsequently verified by ground truthing. In another application of high technology, Lynne Dickson in Edmonton and Michel Robert in Quebec have attached satellite transmitters to King Eiders and Harlequin Ducks in order to track these birds and derive information about their movements that would have been impossible to achieve using earlier tracing technologies.

Developments in molecular biology are also having a profound impact on wildlife studies. Keith Hobson, in Saskatoon, uses stable isotope analysis to delineate particular populations of Monarch Butterflies. Kathy Dickson performs DNA analyses on eastern Harlequin Ducks for the same purpose. With the perfection of such techniques, the value of the CWS Specimen Bank as a resource for researchers has increased steadily.

More than technology has changed over the past 50 years. The number and diversity of government, corporate, and voluntary organizations that influence the status of wildlife and wildlife habitat in Canada have grown significantly. Resource-based industries have profoundly altered the natural face of the country, converting vast, biologically diverse ecosystems into economically profitable but ecologically monotonous landscapes. At the same time, there has been an enormous increase in the number of Canadians who perceive themselves as having a personal responsibility for protecting the world's wilderness. CWS no longer "owns" wildlife science, even in the far north, where it was once virtually the only serious participant in the field. Now, throughout most of the Northwest Territories, multistakeholder wildlife management boards develop priorities and fund research. Aboriginal land claim settlements have already greatly changed the dynamics of northern wildlife stewardship. The establishment of the Inuit-administered territory of Nunavut, in 1999, will further this trend.

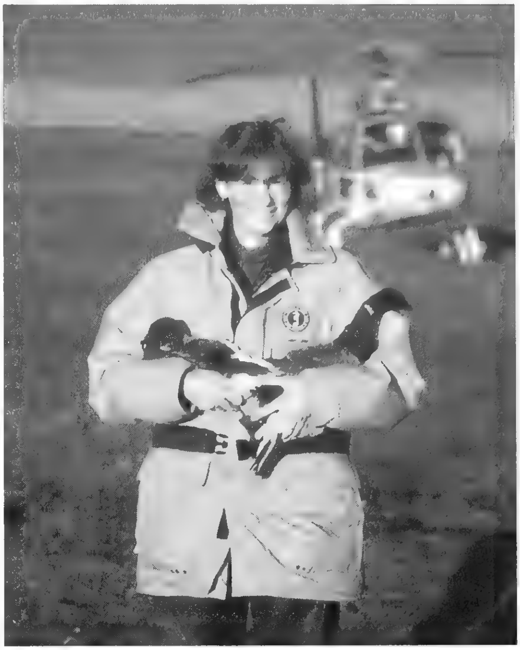
As a result of the increase in the number and influence of stakeholders in wildlife science, wildlife management, and wildlife utilization, a need has emerged to form constructive partnerships, regionally, nationally, and internationally. In many ways, the history of CWS has been shaped by that necessity, initially through Federal–Provincial Wildlife Conferences and latterly through participation in a range of associations that run the gamut from northern comanagement boards to joint conservation ventures like COSEWIC and NAWMP, to international commitments such as CITES and the Convention on Biological Diversity.

A large part of the success of these partnerships is attributable to the fact that CWS has generally managed to steer clear of political entanglements, citing the common desire to protect wildlife as an incentive for collaboration rather than confrontation. As the head of one of Canada's leading nongovernment environmental organizations, Monte Hummel, President of World Wildlife Fund Canada, has been particularly well positioned to observe and evaluate this role. In his words:

> There are a few organizations within government which manage to grow into something more than just another bureaucracy, to emerge with a history, spirit and culture uniquely their own. Such is the Canadian Wildlife Service.
>
> To work with CWS is to work with a group of professionals who actually care about wildlife in Canada. They are seemingly in every nook and cranny of the country, and no matter what the issue, someone somewhere in CWS will have something intelligent to say about it. Sometimes the Service is quietly raising concerns from within; sometimes it tactfully sows concern outside government; and nearly always it is at the table to help broker solutions. In my experience, its principal shortcoming has been the sometimes petty turf wars that have plagued federal/provincial relations in Canada since Confederation. But it has been refreshing to find CWS sharing our frustration when these rivalries impede what's best for wildlife.[2]

Another long-time observer of CWS is Janet Foster, historian, author of the recently republished book *Working for Wildlife*,[3] and, in partnership with John Foster, one of Canada's foremost wildlife film-makers. Asked to provide an "outsider's view" of CWS, she was quick to respond:

> It is quite remarkable how an agency set up principally to administer migratory bird regulations came to assume so many different responsibilities and to handle them so well....I suspect part of the reason for CWS's success is that it has always attracted the "best and the brightest" of personnel — scientists, biologists, field researchers, and many others who began and continued their careers there. I strongly suspect that it's their hard work and diligence that has made CWS the respected organization that it is today.
>
> As natural science film makers, John and I have been privileged to spend time in the field with a number of CWS scientists and wildlife biologists over the past twenty-five years....We've shared bannock and blackflies on many a wilderness campsite in some of the most remote and splendid regions of this land. And we were always struck by the fact that those government biologists really loved being out there, living in tents and on freeze dried food for weeks and months at a time, often under the most appalling weather and wind conditions. You had to love that work to do it, and they did it with such humour and good spirits. Whether they were pitching about in boats and small planes counting whales or seabirds in the High Arctic, or perching all day on windswept hilltops in the north Yukon tracking the movements of caribou, they always had a total commitment to what they were doing, and why there was a need to do it. It's that "need to know," the sense of purpose that, for us, has always characterized the CWS field biologist and, indeed, the Canadian Wildlife Service itself.
>
> More recently, in late March of '97, John and I found ourselves in the back seat of a Canadian Coast Guard helicopter off the coast of northern Labrador. We were flying just thirty metres above a rolling Atlantic swell. In the front seat was Pierre Ryan, a long time CWS technician and seabird specialist. Below and beside us — as we paced them at 100 kmph [kilometres per hour] — were hundreds upon hundreds of murres and fulmars all flying along the ice edge. We were filming from the chopper's open back door and above the roar we could hear Pierre shouting into his tape recorder as he identified species, logging their numbers and position. That March trip on board the Coast Guard ship "Henry Larsen" — the Voisey's Bay Ice Probe — was the first time scientists and biologists had been up the Labrador so early in the year. We had joined the "Larsen" to film icebergs for our television documentary. For Pierre this was (in his words) a "first in a lifetime experience." But it was also part of that vital "need to know." What effects will increased shipping have on seabirds when nickel development comes to the Labrador? It's this kind of knowledge, the gathering of "base line" data, that has been part and parcel of CWS's work over many years and which has probably earned it the greatest respect.
>
> ....The past record speaks for itself: the diversity of responsibilities, the toxicology work, the interpretive programs, the Hinterland "Who's Who" publications, and the countless scientists and biologists whose painstaking, often plodding field work has contributed so much to what we know today about species, habitats and ecosystems....
>
> The Canadian Wildlife Service has had a grand and illustrious past — a "Golden Age" indeed. It's our hope that all Canadians — not just the committed environ-



The continuing importance of waterfowl research and banding activity in Canada's north is illustrated by this photograph of CWS biologist Kathy Dickson with an armload of Brant, taken at Dewey Soper Migratory Bird Sanctuary, Baffin Island, in the summer of 1994 (Photo credit: S. Wendt).

Judith Kennedy (*l.*) and Connie Downes record the bird species seen and heard during a three-minute stop on their Breeding Bird Survey route. Countless CWS employees devote some of their personal time to wildlife conservation and education activities (Photo credit: S. Wendt).

mentalists — will understand the importance and need for its work to continue at the same level of excellence, and somehow ensure that CWS enjoys an equally illustrious future.[4]

It is a popular but unflattering assumption among many Canadians that theirs is a bland country, earnestly committed to peace, order, and good government but mistrustful of adventure or achievement. What a curious and ill-founded prejudice this is! On the contrary, few nations in the 20th century have been more ready to embrace largeness of vision in the definition and stewardship of their identity and heritage, or to take bold intellectual risks in the process.

During the early and middle years of this century, Canadians created, under the umbrella of the federal government, a remarkable variety of agencies that were charged with the task of discovering the excellence of this country, conserving it, and making it known. Over the years, Canada's reputation for excellence has been nurtured and sustained in the eyes of the world by bodies such as the National Research Council, the National Museums, the National Film Board, the Canadian Broadcasting Corporation, the National Gallery, the National Parks Service, and the Canadian Wildlife Service. In creating such organizations, it was Canada's particular genius to recognize that the matters for which they were responsible — communications, history, arts, culture, and science — constituted the nation's heritage. This recognition endowed the agencies with an intrinsic value that transcended the short-term preoccupations of successive governments. As a reflection of that worth they were, in general, given rather broad terms of reference, high-minded goals, modestly adequate budgets, and a significant degree of freedom to do those things they did best and to do them well in alliance with like-minded partners. In the case of CWS, that gift of the freedom to excel has served Canadians and Canada's wildlife exceptionally well.

Notes

1. J. Gauthier and Y. Aubry (editors), *The Breeding Birds of Quebec: Atlas of the Breeding Birds of Southern Quebec* (Montreal: Association québécoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, and Canadian Wildlife Service, Environment Canada, Quebec Region, 1996).
2. Monte Hummel, personal communication, e-mail message addressed to P. Logan, 6 August 1998.
3. Janet Foster, *Working for Wildlife: The Beginning of Preservation in Canada* (Toronto: University of Toronto Press, 1978).
4. Janet Foster, personal communication addressed to P. Logan, 17 July 1998.

About the Author

James Alexander (Sandy) Burnett was born in Toronto in 1941 and has been an avid naturalist since 1947, when his grandfather showed him how to attract Cardinals and Evening Grosbeaks to the backyard bird feeder. Torn between a love of literature and a fascination with the living world, he struck an uneasy compromise between the two in his undergraduate years, spending carefree summers as a park interpreter in Northwestern Ontario while studying English and History during the winter months at the University of Toronto.

Subsequent career choices, including five years as a high school teacher and fifteen with the National Film Board, reduced nature study to the status of a leisure pastime. In 1984, however, he abandoned job security to become a full-time writer. It was an ideal way to combine vocations, especially as the Atlantic Regional Office of CWS welcomed the occasional services of a freelancer with a keen interest in field biology.

An extended series of newspaper articles on wildlife conservation in 1987 and 1988 led to his being commissioned as principal author of *On the Brink: Endangered Species in Canada*. He was a writer and editor for the *1991 State of the Environment Report for Canada* and has been an occasional contributor to periodicals such as *Equinox, Canadian Geographic, Nature Canada,* and *The Conservator*. When not writing on environmental conservation and natural history, he plies his craft as a senior associate, copywriter, and consultant with Hawk Communications Inc., in Moncton. Sandy lives in Sackville, New Brunswick, with his wife, Wendy (Wilson) Burnett, a teacher of French and Linguistics at Mount Allison University.

Editor's Afterword

Sandy Burnett prepared this history under contract to the Canadian Wildlife Service, selected the photographs, and wrote their captions. The project was coordinated by Pat Logan, Canadian Wildlife Service, Ottawa, and the text was copy-edited and indexed by Marla Sheffer. A steering committee of Pat Logan, Tony Keith, and Al Smith oversaw the initial draft and two revisions, and these were reviewed in whole or part by a legion of present and former staff of the Canadian Wildlife Service (see Author's Preface). Supplemental to the narrative history, Tony Erskine volunteered the selected bibliography of research publications of the first fifty years of the service. Publication of this issue has been jointly funded by the Canadian Wildlife Service and The Ottawa Field-Naturalists' Club.

I am indebted to all. It is particularly fitting that *The Canadian Field-Naturalist* publish this history, as many former and present staff members of the Canadian Wildlife Service and its predecessors in federal environmental initiatives have played key roles and held executive positions in the councils and committees of its publisher, The Ottawa Field-Naturalists' Club. This includes terms as editor of *The Canadian Field-Naturalist* by Harrison Lewis (1922–1925) and C. H. D. Clarke (1939–1940), when they were on the staff of National Parks before the formation of CWS, and the continuing contribution as associate editor (ornithology) by Tony Erskine since 1974. In addition, *The Canadian Field-Naturalist* has been, and continues to be, an outlet for some of the significant research and observations of the scientific staff of the Canadian Wildlife Service, and numerous staff members have served as referees on submissions to this journal from elsewhere.

FRANCIS R. COOK
Editor

Selected Index

Selected Publications 1947–1997, from Work by the Canadian Wildlife Service (including Dominion Wildlife Service 1947–1950)

Compiled by ANTHONY J. ERSKINE

Research Scientist Emeritus, C.W.S.-Atlantic Region, P.O. Box 6227, Sackville, New Brunswick E4L 1G6, Canada

(with assistance by Craig Hebert, Tony Keith, Joe Kerekes, Pierre Mineau, Ross Norstrom, Jean Sealy, and Millie Williams)

Erskine, A. J., *Compiler*. 1999. Selected publications 1947–1997, from work by the Canadian Wildlife Service (including Dominion Wildlife Service 1947–1950). Canadian Field-Naturalist 113(1): 184–214.

This list of publications was prepared to enlarge upon the accompanying historical account of the Canadian Wildlife Service (CWS) in illustrating the variety and extent of scientific work carried on in the organization during the 50 years after 1947. A complete bibliography of publications authored, partly or wholly, by CWS personnel and their associates was *not* attempted. The following notes provide some rationale for the selection, although exceptions were made under most criteria. Decisions as to content were left to the compiler, who is no less biased than most readers.

Authors Cited

(i) The listing focussed on publications by CWS staff members. Relatively few by contractors and other investigators who worked for CWS were included. Papers published shortly after a person joined CWS, based on their earlier work, were not included unless that work had been initiated by CWS. Multi-author papers of which the first two or more authors were not CWS people were usually excluded.

Publications Cited

(ii) CWS Progress Notes and CWS Technical Report Series were included quite selectively, as many items in those series were reported more fully later, and others were simply data summaries.

(iii) Compendia edited by CWS personnel, and comprising mainly papers by CWS people, were listed under editor name(s) only; individual papers therein were not listed. Other compendia, with most papers by people outside CWS, had CWS papers listed under authors' name(s).

(iv) Review papers, especially in books and symposium volumes, were usually omitted, as their content often overlapped widely with earlier publications by the same authors.

(v) Faunal papers were included if they contained biogeographic or ecological interpretation. More were included from the early years of CWS, when exploratory (faunal) work made up a larger proportion of the agency's activities.

(vi) Brief distributional or behavioural notes (1–3 pages) were mostly omitted.

(vii) Methodological and administrative papers were usually ignored.

Sources Consulted

(viii) Most CWS publications in the Monograph, Report, and Occasional Papers series were included. Papers by CWS personnel in the "Literature cited" sections of those publications were added, following criteria given above.

(ix) Tables of contents of journals that appeared frequently in the above "Literature cited" sections were searched as far back as local availability allowed, and the "Literature cited" sections of CWS articles therein were scanned in their turn. Journals that appeared less frequently were scanned for titles by CWS authors; search of a journal was soon abandoned if few titles were found. The curve of diminishing returns usually made it obvious when to end a search, and few gaps in coverage remained obvious when local libraries had been worked out. No computerized search was attempted, as publications before 1975 are not adequately sampled by that mode.

(x) Millie Williams (CWS-National Wildlife Research Centre) helped greatly by forwarding comprehensive publication lists maintained by CWS Toxic Substances units, as those were under-represented in my other sources. Publications in those lists were selected following the criteria given above. Joe Kerekes' (CWS-Atlantic Region) work on the long-range transport of air pollutants was also poorly represented, so a list was obtained from him.

I apologize to anyone whose scientific work was not represented adequately in this selection. As noted above, the listing focussed on *scientific* work of CWS. People familiar with this agency will recognize that some of its major activities were largely bypassed in this listing, e.g., enforcement and regulations, habitat, protective treaties and conventions; routine survey work was covered mainly through its contributions to research initiatives. Those "neglected" activities of CWS are based on knowledge that, in part, resulted from scientific investigations by agency staff. The strong scientific base provided by CWS work was long one of its major strengths, and that was the primary focus of this compilation.

Publication List

Adams, G. D., and **G. C. Gentle.** 1978. Spatial changes in waterfowl habitat, 1964–74, on two land types in the Manitoba Newdale Plain. Canadian Wildlife Service Occasional Paper number 38. 27 pages.

Alexander, S. A., T. W. Barry, D. L. Dickson, H. D. Prus, and **K. E. Smyth.** 1988. Key areas for birds in coastal regions of the Canadian Beaufort Sea. Canadian Wildlife Service, Western & Northern Region, Edmonton. 146 pages.

Alexander, S. A., R. S. Ferguson, and **K. J. McCormick.** 1991. Key migratory bird terrestrial habitat sites in the Northwest Territories. 2nd edition. Canadian Wildlife Service Occasional Paper number 71. 184 pages.

Alexander, S. A., K. A. Hobson, C. L. Gratto–Trevor, and **A. W. Diamond.** 1996. Conventional and isotopic determinations of shorebird diets at an inland stopover: the importance of invertebrates and *Potamogeton pectinatus* tubers. Canadian Journal of Zoology 74: 1057–1068.

Alisauskas, R. T., and **K. A. Hobson.** 1993. Determination of lesser snow goose diets and winter distribution using stable isotope analysis. Journal of Wildlife Management 57: 49–54.

Anderson, R. S. 1967. Diaptomid copepods from two mountain ponds in Alberta. Canadian Journal of Zoology 45: 1043–1047.

Anderson, R. S. 1970a. *Diaptomus (Leptodiaptomus) connexus* Light 1938 in Alberta and Saskatchewan. Canadian Journal of Zoology 48: 41–47.

Anderson, R. S. 1970b. The physical and chemical limnology of two mountain lakes in Banff National Park, Alberta. Journal of the Fisheries Research Board of Canada 27: 233–249.

Anderson, R. S. 1970c. Predator–prey relationships and predation rates for crustacean zooplankters from some lakes in western Canada. Canadian Journal of Zoology 48: 1229–1240.

Anderson, R. S., and **F. L. Fabris.** 1970. A new species of diaptomid copepod from Saskatchewan with notes on the crustacean community of the pond. Canadian Journal of Zoology 48: 49–54.

Anderson, R. S., and **L. G. Raasveldt.** 1974. *Gammarus* predation and the possible effects of *Gammarus* and *Chaoborus* feeding on the zooplankton composition in some small lakes and ponds in western Canada. Canadian Wildlife Service Occasional Paper number 18. 23 pages.

Anderson, R. S., and **R. B. Green.** 1976. Limnological and planktonic studies in the Waterton Lakes, Alberta. Canadian Wildlife Service Occasional Paper number 27. 29 pages.

Anonymous. 1969. Saskatoon wetlands seminar. Canadian Wildlife Service Report Series number 6. 262 pages.

Anonymous. 1971. Studies of bird hazards to aircraft. Canadian Wildlife Service Report Series number 14. 104 pages.

Ashley, E. P., and **J. T. Robinson.** 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110: 403–412.

Bailey, R. O. 1981. A theoretical approach to problems in waterfowl management. Transactions North American Wildlife and Natural Resources Conference 46: 58–71.

Bailey, R. O. 1983. Use of southern boreal lakes by moulting and staging diving ducks. Pages 54–59 *in* First western hemisphere waterfowl and waterbird symposium. *Edited by* H. Boyd. Canadian Wildlife Service and International Waterfowl Research Bureau.

Baker, B. E., C. R. Harington, and **A. L. Symes.** 1963. Polar bear milk. I. Gross composition and fat constitution. Canadian Journal of Zoology 41: 1035–1039.

Banasch, U., J. P. Goossen, A. Einstein Riez, C. Casler, and **R. D. Barradas.** 1992. Organochlorine contaminants in migrant and resident prey of Peregrine Falcons, *Falco peregrinus*, in Panama, Venezuela, and Mexico. Canadian Field-Naturalist 106: 493–498.

Bandiera, S. M., S. M. Torok, M. A. Ramsay, and **R. J. Norstrom.** 1995. Catalytic and immunological characterization of hepatic and lung cytochromes P450 in the polar bear. Biochemical Pharmacology 49: 1135–1146.

Banfield, A. W. F. 1949a. An irruption of elk in Riding Mountain National Park, Manitoba. Journal of Wildlife Management 13: 127–134.

Banfield, A. W. F. 1949b. The present status of North American caribou. Transactions North American Wildlife Conference 14: 477–491.

Banfield, A. W. F. 1951a. Populations and movements of the Saskatchewan timber wolf (*Canis lupus knightii*) in Prince Albert National Park, Saskatchewan, 1947 to 1951. Canadian Wildlife Service Wildlife Management Bulletin series 1, number 4. 21 pages.

Banfield, A. W. F. 1951b. Preliminary investigations of the barren-ground caribou. Canadian Wildlife Service Wildlife Management Bulletin, series 1, number 10A & B (2 volumes). 79 & 112 pages.

Banfield, A. W. F. 1951c. Notes on the mammals of the Mackenzie District, N.W.T. Arctic 4: 113–121.

Banfield, A. W. F. 1954a. The role of ice in the distribution of mammals. Journal of Mammalogy 35: 104–107.

Banfield, A. W. F. 1954b. Tularemia in beavers and muskrats, Waterton Lakes National Park, Alberta, 1952–53. Canadian Journal of Zoology 32: 139–143.

Banfield, A. W. F. 1955. A provisional life table for the barren ground caribou. Canadian Journal of Zoology 33: 143–147.

Banfield, A. W. F. 1956. An investigation of ticks as disease vectors in Banff National Park, Alberta. Canadian Journal of Zoology 34: 417–423.

Banfield, A. W. F., and **J. S. Tener.** 1958. A preliminary study of the Ungava caribou. Journal of Mammalogy 39: 560–573.

Baril, A., J. E. Elliott, J. D. Somers, and **G. Erickson.** 1990. Residue levels of environmental contaminants in prey species of the Peregrine Falcon, *Falco peregrinus*, in Canada. Canadian Field-Naturalist 104: 273–284.

Baril, A., B. Jobin, P. Mineau, and **B. T. Collins.** 1994. A consideration on inter-species variability in the use of the median lethal dose (LD50) in avian risk assessment. Canadian Wildlife Service Technical Report Series number 216.

Barr, J. F. 1986. Population dynamics of the Common Loon (*Gavia immer*) associated with mercury-contaminated waters in northwestern Ontario. Canadian Wildlife Service Occasional Paper number 56. 23 pages.

Barry, S. J., and **T. W. Barry.** 1990. Food habits of Glaucous Gulls in the Beaufort Sea. Arctic 43: 43–49.

Barry, T. W. 1956. Observations of a nesting colony of American Brant. Auk 73: 193–202.

Barry, T. W. 1960. Waterfowl reconnaissance in the western Arctic. Arctic Circle 13: 51–58.

Barry, T. W. 1962. Effect of late seasons on Atlantic Brant reproduction. Journal of Wildlife Management 26: 19–26.

Barry, T. W. 1968. Observations on natural mortality and native use of eider ducks along the Beaufort Sea coast. Canadian Field-Naturalist 82: 140–144.

Barry, T. W., and **R. Spencer.** 1976. Wildlife response to oil well drilling. Canadian Wildlife Service Progress Notes number 67. 15 pages.

Bateman, M. C. 1986. Winter habitat use, food habits and home range size of the Marten, *Martes americana*, in western Newfoundland. Canadian Field-Naturalist 100: 58–62.

Beauchamp, S., and **J. Kerekes.** 1980. Comparative changes in water chemistry within impounded and natural freshwater marshes at the Tintamarre National Wildlife Area. Transactions of the Northeast Section of The Wildlife Society 37: 198–209.

Beauchamp, S. T., and **J. Kerekes.** 1989. Effects of acidity and DOC on phytoplankton community structure and production in three acid lakes (Nova Scotia). Water Air Soil Pollution 46: 323–334.

Bédard, J. 1969. Histoire naturelle du Gode, *Alca torda*, L., dans le golfe Saint-Laurent, province du Québec, Canada. Canadian Wildlife Service Report Series number 7. 79 pages.

Beland, P., S. De Guise, C. Girard, A. Lagace, D. Martineau, R. Michaud, D. Muir, R. Norstrom, E. Pelletier, S. Ray, and **L. Shugart.** 1994. Toxic compounds and health and reproductive effects in St. Lawrence beluga whales. Journal of Great Lakes Research, 19: 766–775.

Bélanger, L., and **D. Lehoux.** 1994. Use of a tidal saltmarsh and coastal impoundments by sympatric breeding and staging Black Ducks, *Anas rubripes*, and Mallards, *A. platyrhynchos*. Canadian Field-Naturalist 108: 311–317.

Bélanger, L., and **D. Lehoux.** 1995. Use of various habitat types by nesting ducks on islands in the St. Lawrence River between Montréal and Trois-Rivières. Canadian Wildlife Service Occasional Paper number 87. 24 pages.

Bendell, B. E. 1986. The effects of fish and pH on the distribution and abundance of back-swimmers (Hemiptera: Notonectidae). Canadian Journal of Zoology 64: 2696–2699.

Bendell, B. E., and **D. K. McNicol.** 1987a. Fish predation, lake acidity and the composition of aquatic insect assemblages. Hydrobiologia 150: 193–202.

Bendell, B. E., and **D. K. McNicol.** 1987b. Cyprinid assemblages, and the physical and chemical characteristics of small northern Ontario lakes. Environmental Biology of Fishes 19: 229–234.

Bendell, B. E., and **D. K. McNicol.** 1987c. Estimation of nektonic insect populations. Freshwater Biology 18: 105–108.

Bendell, B. E., and **D. K. McNicol.** 1991. An assessment of leeches (Hirudinea) as indicators of lake acidification. Canadian Journal of Zoology 69: 130–133.

Bendell, B. E., and **D. K. McNicol.** 1993. Gastropods from small northeastern Ontario lakes: Their value as indicators of acidification. Canadian Field-Naturalist 107: 267–272.

Bendell, B. E., and **D. K. McNicol.** 1995a. The diet of insectivorous ducklings and the acidification of small Ontario lakes. Canadian Journal of Zoology 73: 2044–2051.

Bendell, B. E., and **D. K. McNicol.** 1995b. Lake acidity, fish predation, and the distribution and abundance of some littoral insects. Hydrobiologia 302: 133–145.

Benson, D. A. 1971. The Canada migratory game bird hunting permit and related surveys. Canadian Wildlife Service Occasional Paper number 11. 15 pages.

Bergman, A., R. J. Norstrom, K. Haraguchi, H. Kuroki, and **P. Beland.** 1994. PCB and DDE methyl sulphones in mammals from Canada and Sweden. Environmental Toxicology and Chemistry 13: 121–128.

Berrill, M., S. Bertram, L. McGillivray, M. Kolohon, and **B. Pauli.** 1994. Effects of low concentrations of forest–use pesticides on frog embryos and tadpoles. Environmental Toxicological Chemistry 13: 657–664.

Beznaczuk, H. 1980. Hunter mobility – its relationship to hunter characteristics and its effect on estimated waterfowl harvest distribution. Canadian Wildlife Service Progress Notes number 109. 16 pages.

Birkhead, T. R., and **D. N. Nettleship.** 1980. Census methods for murres, *Uria* species: a unified approach. Canadian Wildlife Service Occasional Paper number 43. 23 pages.

Birkhead, T. R., and **D. N. Nettleship.** 1981. Reproductive biology of the Thick–billed Murre — an inter–colony comparison. Auk 98: 258–269.

Birkhead, T. R., and **D. N. Nettleship.** 1982. The adaptive significance of egg-size and laying–date in Thick-billed Murres, *Uria lomvia*. Ecology 63: 300–306.

Birkhead, T. R., and **D. N. Nettleship.** 1984a. Egg size, composition and offspring quality in some Alcidae (Aves: Charadriiformes). Journal of Zoology, London, 202: 177–194.

Birkhead, T. R., and **D. N. Nettleship.** 1984b. Alloparental care in the common murre (*Uria aalge*). Canadian Journal of Zoology 62: 2121–2124.

Birkhead, T. R., and **D. N. Nettleship.** 1987. Ecological relationships between Common Murres, *Uria aalge*, and Thick-billed Murres, *Uria lomvia*, at the Gannet Islands, Labrador. I. Morphometrics and timing of breeding. II. Breeding success and site characteristics. III. Feeding ecology of the young. Canadian Journal of Zoology 65: 1621–1629; 1630–1637; 1638–1649.

Birkhead, T. R., and **D. N. Nettleship.** 1995. Arctic fox influence on a seabird community in Labrador: a natural experiment. Wilson Bulletin 107: 397–412.

Birkhead, T. R., J. D. Biggins, and **D. N. Nettleship.** 1980. Non-random, intra-colony distribution of bridled guillemots *Uria aalge*. Journal of Zoology (London) 192: 9–16.

Birkhead, T. R., E. Greene, J. D. Biggins, and **D. N. Nettleship.** 1985. Breeding site characteristics and reproductive success in thick-billed murres. Canadian Journal of Zoology 63: 1880–1884.

Bishop, C. A., R. J. Brooks, J. H. Carey, P. Ng, R. J. Norstrom, and **D. R. S. Lean.** 1991. The case for a cause-effect linkage between environmental contamination and development in eggs of the common Snapping Turtle (*Chelydra s. serpentina*) from Ontario, Canada. Journal of Toxicology and Environmental Health 33: 521–547.

Bishop, C. A., and **K. E. Pettit.** *Editors.* 1992. Declines in Canadian amphibian populations: designing a national monitoring strategy. Canadian Wildlife Service Occasional Paper number 76. 117 pages.

Bishop, C. A., D. V. Weseloh, N. M. Burgess, J. Struger, R. J. Norstrom, R. Turle, and **K. A. Logan.** 1992. An atlas of contaminants in eggs of fish-eating colonial birds of the Great Lakes (1970–1988). Volumes I & II. Accounts by locations and species. Canadian Wildlife Service Technical Report Series numbers 152 & 153.

Bishop, C. A., M. D. Koster, A. A. Chek, D. J. T. Hussell, and **K. Jock.** 1995. Chlorinated hydrocarbons and mercury in sediments, Red-winged Blackbirds (*Agelaius phoeniceus*) and Tree Swallows (*Tachycineta bicolor*) from wetlands in the Great Lakes – St. Lawrence River Basin. Environmental Toxicology and Chemistry 14: 491–501.

Blancher, P. J. 1991. Acidification: Implications for wildlife. Transactions North American Wildlife and Natural Resources Conference 56: 195–204.

Blancher, P. J., and **D. G. McAuley.** 1987. Influence of wetland acidity on avian breeding success. Transactions North American Wildlife and Natural Resources Conference 52: 628–635.

Blancher, P. J., and **D. K. McNicol.** 1987. Peatland water chemistry in central Ontario in relation to acid deposition. Water Air Soil Pollution 35: 217–232.

Blancher, P. J., and **D. K. McNicol.** 1988. Breeding biology of tree swallows in relation to wetland acidity. Canadian Journal of Zoology 66: 842–849.

Blancher, P. J., and **D. K. McNicol.** 1991. Tree swallow diet in relation to wetland acidity. Canadian Journal of Zoology 69: 2629–2637.

Blancher, P. J., D. K. McNicol, R. K. Ross, C. H. R. Wedeles, and **P. Morrison.** 1992. Towards a model of acidification effects on waterfowl in eastern Canada. Environmental Pollution 78: 57–63.

Blokpoel, H. 1973. Bird migration forecasts for military air operations. Canadian Wildlife Service Occasional Paper number 16. 17 pages.

Blokpoel, H. 1974a. Migration of Lesser Snow and Blue Geese in spring across southern Manitoba. Part 1: Distribution, chronology, directions, numbers, heights and speed. Canadian Wildlife Service Report Series number 28. 29 pages.

Blokpoel, H. 1974b. Recent changes in chronology of spring Snow Goose migration from southern Manitoba. Canadian Field-Naturalist 88: 67–71.

Blokpoel, H. 1976. Bird hazards to aircraft. Problems and prevention of bird/aircraft collisions. Clarke, Irwin & Co. Ltd., with Environment Canada and Supply and Services Canada. 236 pages.

Blokpoel, H. 1977. Gulls and terns nesting in northern Lake Ontario and the upper St. Lawrence River. Canadian Wildlife Service Progress Notes number 75. 12 pages.

Blokpoel, H. 1981. An attempt to evaluate the impact of cannon–netting in Caspian Tern colonies. Colonial Waterbirds 4: 61–67.

Blokpoel, H., and **J. Burton.** 1975. Weather and height of nocturnal migration in eastcentral Alberta: a radar study. Bird–Banding 46: 311–328.

Blokpoel, H., and **M. C. Gauthier.** 1975. Migration of Lesser Snow and Blue Geese in spring across southern Manitoba. Part 2: Influence of the weather and prediction of major flights. Canadian Wildlife Service Report Series number 32. 24 pages.

Blokpoel, H., and **P. M. Fetterolf.** 1978. Colonization by gulls and terns of the Eastern Headland, Toronto Outer Harbour. Bird-Banding 49: 59–65.

Blokpoel, H., and **G. B. McKeating.** 1978. Fish–eating birds nesting in Canadian Lake Erie and adjacent waters. Canadian Wildlife Service Progress Notes number 87. 12 pages.

Blokpoel, H., and **G. T. Haymes.** 1979. Origins of Ring-billed Gulls at a new colony. Bird-Banding 50: 210–215.

Blokpoel, H., and **P. A. Courtney.** 1980. Site tenacity in a new Ring-billed Gull colony. Journal of Field Ornithology 51: 1–5.

Blokpoel, H., and **M. C. Gauthier.** 1980. Weather and the migration of Canada Geese across southeastern Ontario in spring 1975. Canadian Field-Naturalist 94: 293–299.

Blokpoel, H., and **P. A. Courtney.** 1982. Immigration and recruitment of Ring-billed Gulls and Common Terns on the lower Great Lakes. Canadian Wildlife Service Progress Notes number 133. 12 pages.

Blokpoel, H., and **G. D. Tessier.** 1984. Overhead wires and monofilament lines exclude Ring-billed Gulls from public places. Wildlife Society Bulletin 12: 55–58.

Blokpoel, H., and **G. D. Tessier.** 1986. The Ring-billed Gull in Ontario: a review of a new problem species. Canadian Wildlife Service Occasional Paper number 57. 32 pages.

Blokpoel, H., and **J. Struger.** 1988. Cherry depredation by Ring-billed Gulls, *Larus delawarensis*, in the Niagara Region, Ontario. Canadian Field-Naturalist 102: 430–433.

Blokpoel, H., and **W. C. Scharf.** 1991. The Ring-billed Gull in the Great Lakes of North America. Acta Congressus Internationalis Ornithologicus 20: 2372–2377.

Blokpoel, H., and **G. D. Tessier.** 1993. Atlas of colonial waterbirds nesting on the Canadian Great Lakes, 1989–1991. Part 1. Cormorants, gulls and island–nesting terns on Lake Superior in 1989. Canadian Wildlife Service Technical Report Series number 181. 96 pages. Parts 2–4 followed in 1996–1997.

Blokpoel, H., and **J. Neuman.** 1997. Sound levels in 3 Ring-billed Gull colonies of different size. Colonial Waterbirds 20: 221–226.

Blokpoel, H., P. M. Catling, and **G. T. Haymes.** 1978. Relationship between nest sites of common terns and vegetation on the Eastern Headland, Toronto Outer Harbour. Canadian Journal of Zoology 56: 2057–2061.

Blokpoel, H., J. P. Ryder, I. Seddon, and **W. R. Carswell.** 1980. Colonial waterbirds nesting in Canadian Lake Superior in 1978. Canadian Wildlife Service Progress Notes number 118. 13 pages.

Blokpoel, H., R. D. Morris, and **P. Trull.** 1982. Winter observations of Common Terns in Trinidad, Guyana and Suriname. Colonial Waterbirds 5: 144–147.

Blokpoel, H., R. D. Morris, and **G. D. Tessier.** 1984. Field investigations of the biology of Common Terns wintering in Trinidad. Journal of Field Ornithology 55: 424–434.

Blokpoel, H., C. L. Casler, F. Espinoza, G. D. Tessier, and **J. R. Lira.** 1984. Distribution and numbers of large terns in northwestern Venezuela during 26 January – 5 February 1983. Colonial Waterbirds 7: 111–116.

Blokpoel, H., P. J. Blancher, and **P. M. Fetterolf.** 1985. On the plumage of nesting Ring–billed Gulls of different ages. Journal of Field Ornithology 56: 113–124.

Blokpoel, H., G. D. Tessier, and **A. Harfenist.** 1987. Distribution during post-breeding dispersal, migration, and overwintering of Common Terns color-marked on the lower Great Lakes. Journal of Field Ornithology 58: 206–217.

Blood, D. A. 1966. The *Festuca scabrella* association in Riding Mountain National Park, Manitoba. Canadian Field-Naturalist 80: 24–32.

Blood, D. A. 1968. Range relationships of elk and cattle in Riding Mountain National Park, Manitoba. Canadian Wildlife Service Wildlife Management Bulletin, series 1, number 19. 62 pages + map.

Blood, D. A., and **A. L. Lovaas.** 1966. Measurements and weight relationships in Manitoba elk. Journal of Wildlife Management 30: 135–140.

Blood, D. A., J. R. McGillis, and **A. L. Lovaas.** 1967. Weights and measurements of moose in Elk Island National Park, Alberta. Canadian Field-Naturalist 81: 263–269.

Blood, D. A., D. R. Flook, and **W. D. Wishart.** 1970. Weights and growth of Rocky Mountain bighorn sheep in western Alberta. Journal of Wildlife Management 34: 451–455.

Boersma, D. C., J. A. Ellenton, and **A. Yagimas.** 1985. Investigation of the hepatic mixed-function oxidase system in Herring Gull embryos in relation to environmental contaminants. Environmental Toxicology and Chemistry 5: 309–318.

Boily, M. H., L. Champoux, D. H. Bourbonnais, J.-L. DesGranges, J. Rodrigue, and **P. A. Spear.** 1994. β-carotene and retinoids in eggs of Great Blue Herons (*Ardea herodias*) in relation to St. Lawrence River contamination. Ecotoxicology 3: 271–286.

Bonin, J., J.-L. DesGranges, C. Bishop, J. Rodrigue, A. Gendron, and **J. Elliott.** 1995. Comparative study of xenobiotic contaminants in Mudpuppy (Amphibia) and the Common Snapping Turtle (Reptilia), St. Lawrence River, Canada. Archives Environmental Contamination and Toxicology 28: 184–194.

Boutin, C., and **P. A. Keddy.** 1993. A functional classification of wetland plants for predictive community ecology. Journal of Vegetation Science 4/5: 591–600.

Boutin, C., K. E. Freemark, D. V. Weseloh, G. M. Donaldson, M. Csizy, P. A. Martin, A. Wormington, J. McCracken, and **D. Shepherd.** 1996. Bird use of crops in southern Ontario: Implications for assessment of pesticide risk. Canadian Wildlife Service Technical Report Series number 264.

Boyd, H., *Editor*. 1974. Canadian Wildlife Service waterfowl studies in eastern Canada, 1969–73. Canadian Wildlife Service Report Series number 29. 105 pages.

Boyd, H. 1975. Planning for wildlife in Canada. Transactions North American Wildlife and Natural Resources Conference 40: 97–102.

Boyd, H. 1976a. Mortality rates of Hudson Bay Snow Geese, 1967–74. Canadian Wildlife Service Progress Notes number 61. 4 pages.

Boyd, H. 1976b. Estimates of total numbers in the Hudson Bay population of Lesser Snow Geese, 1964–1973. Canadian Wildlife Service Progress Notes number 63. 7 pages.

Boyd, H. 1977. Waterfowl hunting by native peoples in Canada: The case of James Bay and northern Quebec. Transactions International Congress of Game Biologists 13: 463–473.

Boyd, H. 1979. Management of *Branta bernicla* in Canada. Pages 181–197 *in* Proceedings First Technical Meeting Western Palearctic Migratory Bird Management. International Waterfowl Research Bureau, Slimbridge, U.K.

Boyd, H. 1981. Prairie dabbling ducks, 1941–1990. Canadian Wildlife Service Progress Notes number 119. 9 pages.

Boyd, H. 1983. Intensive regulation of duck hunting in North America: its purpose and achievements. Canadian Wildlife Service Occasional Paper number 50. 22 pages.

Boyd, H. 1985a. The large-scale impact of agriculture on ducks in the Prairie Provinces, 1956–81. Canadian Wildlife Service Progress Notes number 149. 13 pages.

Boyd, H. 1985b. The reported kill of ducks and geese in Canada and the USA, 1974–82. Canadian Wildlife Service Occasional Paper number 55. 19 pages.

Boyd, H. 1990. Duck numbers in the USSR, the Western Palearctic and North America 1967–86: first comparisons. Wildfowl 41: 171–175.

Boyd, H. 1992. Arctic summer conditions and British Knot numbers: an exploratory analysis. Wader Study Group Bulletin 64 (Supplement): 144–152.

Boyd, H. 1995. The influence of weather on catches of ducks in Steeple Decoy, Essex, in 1714–1726. Wildfowl 46: 89–98.

Boyd, H. 1997. A view from above. Wildfowl 47: 9–16.

Boyd, H. 1997. P. M. Scott on geese on the Wash and the Solway Firth, 1927–1933. Wildfowl 47: 204–211.

Boyd, H., and **G. H. Finney.** 1978. Migratory game bird hunters and hunting in Canada. Canadian Wildlife Service Report Series number 43. 125 pages.

Boyd, H., and **L. S. Maltby.** 1979. The Brant of the western Queen Elizabeth Islands, N.W.T. Pages 5–21 *in* Proceedings Symposium "Biology and management of Pacific Flyway geese". *Edited by* R. L. Jarvis and J. C. Bartonek. Portland, Oregon.

Boyd, H., and **L. S. Maltby.** 1980. Weights and primary growth of Brent Geese (*Branta bernicla*) molting in Queen Elizabeth Islands, N.W.T., Canada. Ornis Scandinavica 11: 135–141.

Boyd, H., and **F. G. Cooch.** 1983. Duck numbers and duck hunting in southern Alberta, 1975–82, and their implications for waterfowl management. Canadian Wildlife Service Progress Notes number 140. 24 pages.

Boyd, H., and **F. G. Cooch.** 1986. Recent changes in sales of Migratory Game Bird Hunting Permits and prospects for the near future. Canadian Wildlife Service Progress Notes number 162. 15 pages.

Boyd, H., G. E. J. Smith, and **F. G. Cooch.** 1982. The Lesser Snow Geese of the eastern Canadian Arctic. Canadian Wildlife Service Occasional Paper number 46. 23 pages.

Boyd, H., L. S. Maltby, and **A. Reed.** 1988. Differences in the plumage patterns of Brant breeding in High Arctic Canada. Canadian Wildlife Service Progress Notes number 174. 9 pages.

Boyer, G. F. 1959. Hand-reared Mallard releases in the Maritime Provinces. Canadian Field-Naturalist 73: 1–5.

Boyer, G. F. 1966. Birds of the Nova Scotia – New Brunswick border region. Canadian Wildlife Service Occasional Paper number 8. 52 pages.

Boyer, G. F., and **O. E. Devitt.** 1961. A significant increase in the birds of Luther Marsh, Ontario, following fresh–water impoundment. Canadian Field-Naturalist 75: 225–237.

Brace, R. K., R. S. Pospahala, and **R. J. Blohm.** 1981. Evaluation of stabilized season lengths and bag limits for hunting ducks in the United States and the Prairie Provinces of Canada. Transactions of the North American Wildlife and Natural Resources Conference 46: 35–43.

Braune, B. M., and **R. J. Norstrom.** 1989. Dynamics of organochlorine compounds in Herring Gulls (*Larus argentatus*): III. Tissue distribution and bioaccumulation in Lake Ontario gulls and organochlorines in Lake Ontario. Environmental Toxicology and Chemistry 8: 957–968.

Braune, B. M., R. J. Norstrom, M. P. Wong, B. T. Collins, and **J. Lee.** 1991. Geographical distribution of metals in livers of polar bears from the Northwest Territories, Canada. Science of the Total Environment 100: 283–299.

Braune, B. M., M. P. Wong, J. C. Belle–Isles, and **W. K. Marshall.** 1991. Chemical residues in Canadian game birds. Canadian Wildlife Service Technical Report number 124. 375 pages.

Broughton, E., and **L. P. E. Choquette.** 1969. Additional information and comments on disease conditions and parasites of barren-ground caribou. Transactions Federal–Provincial Wildlife Conference 33: 30–39.

Broughton, E., L. P. E. Choquette, J. G. Cousineau, and **F. L. Miller.** 1970. Brucellosis in reindeer, *Rangifer tarandus* L., and the migratory barren-ground caribou, *Rangifer tarandus groenlandicus* (L.), in Canada. Canadian Journal of Zoology 48: 1023–1027.

Brown, R. G. B. 1968. Sea birds in Newfoundland and Greenland waters, April-May 1966. Canadian Field-Naturalist 82: 88–102.

Brown, R. G. B. 1974. Bird damage to fruit crops in the Niagara Peninsula. Canadian Wildlife Service Report Series number 27. 56 pages.

Brown, R. G. B. 1976a. Seabirds of South America and the north west Atlantic. Proceedings International Ornithological Congress 16: 716–724.

Brown, R. G. B. 1976b. The foraging range of breeding Dovekies *Alle alle*. Canadian Field-Naturalist 90: 166–168.

Brown, R. G. B. 1977. Atlas of eastern Canadian seabirds. Supplement 1. Canadian Wildlife Service. 24 pages.

Brown, R. G. B. 1979. Seabirds of the Senegal upwelling and adjacent waters. Ibis 121: 283–292.

Brown, R. G. B. 1980. Seabirds as marine animals. Pages 1–39 *in* Behavior of marine animals. Volume 4. Marine birds. *Edited by* J. Burger, B. L. Olla, and H. E. Winn. Plenum Press, New York.

Brown, R. G. B. 1984. Seabirds in the Greenland, Barents and Norwegian Seas, February-April 1982. Polar Research 2: 1–18.

Brown, R. G. B. 1986. Revised atlas of eastern Canadian seabirds. 1. Shipboard surveys. Canadian Wildlife Service. 111 pages.

Brown, R. G. B. 1988a. Zooplankton patchiness and seabird distributions. Acta Congressus Internationalis Ornithologicus 19: 1001–1016.

Brown, R. G. B. 1988b. The wing–moult of fulmars and shearwaters (Procellariidae) in Canadian Atlantic waters. Canadian Field-Naturalist 102: 203–208.

Brown, R. G. B. 1988c. The influence of hydrographic anomalies on the distributions of storm-petrels (Hydrobatidae) in Nova Scotian waters. Colonial Waterbirds 11: 1–8.

Brown, R. G. B., and **D. N. Nettleship.** 1984. Capelin and seabirds in the northwest Atlantic. Pages 184–194 *in* Marine birds: their feeding ecology and commercial fisheries relationships. Canadian Wildlife Service and Pacific Seabird Group. *Edited by* D. N. Nettleship, G. A. Sanger, and F. Springer.

Brown, R. G. B., and **D. E. Gaskin.** 1988. The pelagic ecology of the Gray and Red–necked Phalaropes (*Phalaropus fulicarius* and *P. lobatus*) in the Bay of Fundy, eastern Canada. Ibis 130: 234–250.

Brown, R. G. B., and **D. E. Gaskin.** 1989. Summer zooplankton distributions at the surface of the outer Bay of Fundy, eastern Canada. Canadian Journal of Zoology 67: 2725–2730.

Brown, R. G. B., D. I. Gillespie, A. R. Lock, P. A. Pearce, and **G. H. Watson.** 1973. Bird mortality from oil slicks off eastern Canada, February-April 1970. Canadian Field-Naturalist 87: 225–234.

Brown, R. G. B., F. Cooke, P. K. Kinnear, and **E. L. Mills.** 1975. Summer seabird distribution in Drake Passage and off southern South America. Ibis 117: 339–356.

Brown, R. G. B., D. N. Nettleship, P. Germain, C. E. Tull, and **T. Davis.** 1975. Atlas of eastern Canadian seabirds. Canadian Wildlife Service. 220 pages.

Brown, R. G. B., S. P. Barker, and **D. E. Gaskin.** 1979. Daytime surface swarming by *Meganyctiphanes norvegica* (M.Sars) (Crustacea, Euphausiacea) off Brier Island, Bay of Fundy. Canadian Journal of Zoology 57: 2285–2291.

Brown, R. G. B., S. P. Barker, D. E. Gaskin, and **M. R. Sandeman.** 1981. The foods of Great and Sooty Shearwaters *Puffinus gravis* and *Puffinus griseus* in eastern Canadian waters. Ibis 123: 19–30.

Busby, D. G., L.-M. White, P. A. Pearce, and **P. Mineau.** 1989. Fenitrothion effects on forest songbirds: a critical new look. Pages 43–108 *in* Environmental effects of fenitrothion use in forestry. *Edited by* W. R. Ernst, P. A. Pearce, and T. L. Pollock. Environment Canada, Dartmouth, Nova Scotia.

Butler, R. G., A. Harfenist, F. A. Leighton, and **D. B. Peakall.** 1988. Impact of sublethal oil and emulsion exposure on the reproductive success of Leach's Storm-Petrels: Short and long–term effects. Journal of Applied Ecology 25: 125–143.

Butler, R. W. 1988. Population dynamics and migration routes of Tree Swallows, *Tachycineta bicolor*, in North America. Journal of Field Ornithology 59: 395–402.

Butler, R. W. 1993. Time of breeding in relation to food availability of female Great Blue Herons (*Ardea herodias*). Auk 110: 693–701.

Butler, R. W. 1994. Population regulation of wading ciconiiform birds. Colonial Waterbirds 17: 166–176.

Butler, R. W. 1995. The patient predator: foraging and population ecology of the Great Blue Heron *Ardea herodias* in British Columbia. Canadian Wildlife Service Occasional Paper number 86. 42 pages.

Butler, R. W., and **R. W. Campbell.** 1987. The birds of the Fraser River delta: populations, ecology and international significance. Canadian Wildlife Service Occasional Paper number 65. 71 pages.

Butler, R. W., and **K. Vermeer.** *Editors.* 1994. The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia. Canadian Wildlife Service Occasional Paper number 83. 76 pages.

Butler, R. W., and **G. W. Kaiser.** 1995. Migration chronology, sex ratio, and body mass of Least Sandpipers in British Columbia. Wilson Bulletin 107: 413–422.

Butler, R. W., B. G. Stushnoff, and **E. McMackin.** 1986. The birds of Creston Valley and southeastern British Columbia. Canadian Wildlife Service Occasional Paper number 58. 35 pages.

Butler, R. W., G. W. Kaiser, and **G. E. J. Smith.** 1987. Migration chronology, length of stay, sex ratio, and weight of Western Sandpipers (*Calidris mauri*) on the south coast of British Columbia. Journal of Field Ornithology 58: 103–111.

Butler, R. W., A. M. Breault, and **T. M. Sullivan.** 1990. Measuring animals through a telescope. Journal of Field Ornithology 61: 111–114.

Butler, R. W., P. E. Whitehead, A. M. Breault, and **I. E. Moul.** 1995. Colony effects on fledging success of Great Blue Herons (*Ardea herodias*) in British Columbia. Colonial Waterbirds 18: 159–165.

Butler, R. W., F. S. Delgado, H. de la Cueva, V. Pulido, and **B. K. Sandercock.** 1996. Migration routes of the Western Sandpiper. Wilson Bulletin 108: 662–672.

Butler, R. W., T. D. Williams, N. Warnock, and **M. A. Bishop.** 1997. Wind assistance: A requirement for migration of shorebirds. Auk 114: 456–466.

Cade, T. J., and **R. Fyfe.** 1970. The North American Peregrine survey, 1970. Canadian Field-Naturalist 84: 231–245.

Cairns, A., and **E. S. Telfer.** 1980. Habitat use by 4 sympatric ungulates in boreal mixedwood forest. Journal of Wildlife Management 44: 849–857.

Cantin, M., A. Bourget, G. Chapdelaine, and **W. G. Alliston.** 1976. Distribution et écologie de la reproduction du Canard chipeau *Anas strepera* au Québec. Le Naturaliste canadien 103: 469–481.

Carbyn, L. N. 1971. Description of the *Festuca scabrella* association in Prince Albert National Park, Saskatchewan. Canadian Field-Naturalist 85: 25–30.

Carbyn, L. N. 1974. Wolf population fluctuations in Jasper National Park, Alberta. Biological Conservation 6: 94–101.

Carbyn, L. N. 1975. Factors influencing activity patterns of ungulates at mineral licks. Canadian Journal of Zoology 53: 377–384.

Carbyn, L. N. 1982. Coyote population fluctuations and spatial distribution in relation to wolf territories in Riding Mountain National Park, Manitoba. Canadian Field-Naturalist 96: 176–182.

Carbyn, L. N., *Editor*. 1982. Wolves in Canada and Alaska. Canadian Wildlife Service Report Series number 45. 133 pages.

Carbyn, L. N. 1983. Wolf predation on elk in Riding Mountain National Park, Manitoba. Journal of Wildlife Management 47: 963–976.

Carbyn, L. N., and **D. Patriquin.** 1983. Observations on home range sizes, movements and social organization of Lynx, *Lynx canadensis*, in Riding Mountain National Park, Manitoba. Canadian Field-Naturalist 97: 262–267.

Carbyn, L. N., and **T. Trottier.** 1987. Responses of bison on their calving grounds to predation by wolves in Wood Buffalo National Park. Canadian Journal of Zoology 65: 2072–2078.

Carbyn, L. N., and **T. Trottier.** 1988. Descriptions of wolf attacks on bison calves in Wood Buffalo National Park. Arctic 41: 297–302.

Carbyn, L. N., S. M. Oosenbrug, and **D. W. Anions.** 1993. Wolves, bison and the dynamics related to the Peace-Athabasca Delta in Canada's Wood Buffalo National Park. Canadian Circumpolar Institute, University of Alberta, Edmonton, Circumpolar Research Series number 4. 270 pages.

Carrière, D., K. L. Fischer, D. B. Peakall, and **P. Anghern.** 1986. Effects of dietary aluminum sulphate on reproductive success and growth of Ringed Turtle-Doves (*Streptopelia risoria*). Canadian Journal of Zoology 64: 1500–1505.

Carter, B. C. 1958. The American Goldeneye in central New Brunswick. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 9. 47 pages.

Caswell, F. D., G. S. Hochbaum, and **R. K. Brace.** 1985. The effect of restrictive regional hunting regulations on survival rates and local harvests of southern Manitoba Mallards. Transactions of the North American Wildlife and Natural Resources Conference 50: 549–556.

Caswell, F. D., G. S. Hochbaum, D. J. Nieman, and **B. C. Turner.** 1987. Temporal and geographic differences of Mallard survival/recovery rates in prairie Canada. Transactions of the North American Wildlife and Natural Resources Conference 52: 285–297.

Champoux, L. 1996. PCBs, dioxins and furans in Hooded Merganser (*Lophodytes cucullatus*), Common Merganser (*Mergus merganser*) and Mink (*Mustela vison*) collected along the St. Maurice River near La Tuque, Quebec. Environmental Pollution 92: 147–153.

Chapdelaine, G., and **A. Bourget.** 1981. Distribution, abondance et fluctuations des populations d'oiseaux marins de l'archipel de Mingan (Golfe du Saint-Laurent, Québec). Le Naturaliste canadien 108: 219–227.

Chapdelaine, G., and **P. Laporte.** 1982. Population, reproductive success, and analysis of contaminants in Razorbills (*Alca torda*) in the estuary and Gulf of St. Lawrence, Quebec. Canadian Wildlife Service Progress Notes number 129. 10 pages.

Chapdelaine, G., and **F. Brousseau.** 1992. Distribution, abundance, and changes of seabird populations of the Gaspé Peninsula, Québec, 1979–1989. Canadian Field-Naturalist 106: 427–434.

Chapdelaine, G., and **J. Bédard.** 1995. Recent changes in the abundance and distribution of the Double-crested Cormorant in the St. Lawrence River, estuary and Gulf, Québec, 1978–1990. Pages 70–77 *in* The Double-crested Cormorant: Biology, conservation and management. *Edited by* D. N. Nettleship and D. C. Duffy. Colonial Waterbirds 18 (Special Publication 1).

Chapdelaine, G., and **P. Brousseau.** 1996. Diet of Razorbill *Alca torda* chicks and breeding success in the St. Mary's Islands, Gulf of St. Lawrence, Quebec, Canada, 1990–1992. Canadian Wildlife Service Occasional Paper 91: 27–36.

Chapdelaine, G., A. J. Gaston, and **P. Brousseau.** 1986. Censusing the Thick-billed Murre colonies of Akpatok Island, NWT. Canadian Wildlife Service Progress Notes number 163. 9 pages.

Chapdelaine, G., P. Laporte, and **D. N. Nettleship.** 1987. Population, productivity and DDT contamination trends of Northern Gannets (*Sula bassanus*) at Bonaventure Island, Quebec, 1967–1984. Canadian Journal of Zoology 65: 2922–2926.

Choquette, L. P. E., and **T. W. M. Cameron.** 1963. Parasitological problems in high northern latitudes with particular reference to Canada. Polar Record 11: 567–577.

Choquette, L. P. E., L. N. Whitton, G. Rankin, and **C. M. Seal.** 1957. Notes on parasites found in reindeer (*Rangifer tarandus*) in Canada. Canadian Journal of Comparative Medicine 21: 199–203.

Choquette, L. P. E., J. F. Gallivan, J. L. Byrne, and **J. Pilipavicius.** 1961. Parasites and diseases of bison in Canada. 1. Tuberculosis and some other pathological conditions in bison at Wood Buffalo and Elk Island National Parks in the fall and winter of 1959–60. Canadian Veterinary Journal 2: 168–174.

Choquette, L. P. E., G. G. Gibson, and **A. M. Pearson.** 1969. Helminths of the grizzly bear, *Ursus arctos* L., in northern Canada. Canadian Journal of Zoology 47: 167–170.

Choquette, L. P., E. Broughton, A. A. Cuerrier, J. G. Cousineau. and **N. S. Novakowski.** 1972. Parasites and diseases of bison in Canada. III. Anthrax outbreaks in the last decade in northern Canada and control measures. Canadian Field-Naturalist 86: 127–132.

Choquette, L. P. E., G. G. Gibson, E. Kuyt, and **A. M. Pearson.** 1973. Helminths of wolves, *Canis lupus* L., in the Yukon and Northwest Territories. Canadian Journal of Zoology 51: 1087–1091.

Chu, I., D. C. Villeneuve, V. E. Valli, L. Ritter, R. J. Norstrom, and **J. J. Ryan.** 1984. Toxicological response and its reversibility in rats fed Lake Ontario or Pacific Coho Salmon for 13 weeks. Journal of Environmental Science and Health B19: 713–732.

Clark, R. G., and **G. C. Gentle.** 1990. Estimates of grain passage time in captive mallards. Canadian Journal of Zoology 68: 2275–2279.

Clark, R. G., and **T. D. Nudds.** 1991. Habitat patch size and duck nesting success: The crucial experiments have not been performed. Wildlife Society Bulletin 19: 534–543.

Clark, R. G., and **A. W. Diamond.** 1993. Restoring upland habitats in the Canadian prairies: Lost opportunity or management by design? Transactions of the North American Wildlife and Natural Resources Conference 58: 551–564.

Clark, R. G., and **B. K. Wobeser.** 1997. Making sense of scents: effects of odour on survival of simulated duck nests. Journal of Avian Biology 28: 31–37.

Clark, R. G., H. Greenwood, and **L. G. Sugden.** 1986a. Estimation of grain wasted by field-feeding ducks in Saskatchewan. Journal of Wildlife Management 50: 184–189.

Clark, R. G., H. Greenwood, and **L. G. Sugden.** 1986b. Influence of grain characteristics on optimal diet of field-feeding Mallards. Journal of Applied Ecology 23: 763–772.

Clark, R. G., L. G. Sugden, R. K. Brace, and **D. J. Nieman.** 1988. The relationship between nesting chronology and vulnerability to hunting of dabbling ducks. Wildfowl 39: 137–144.

Clark, R. G., P. C. James, and **J. B. Morari.** 1991. Sexing adult and yearling American Crows by external measurements and discriminant analysis. Journal of Field Ornithology 62: 132–138.

Clark, R. G., T. D. Nudds, and **R. O. Bailey.** 1991. Populations and nesting success of upland-nesting ducks in relation to cover establishment. Canadian Wildlife Service Progress Notes, number 193. 6 pages.

Clark, R. G., H. Boyd, and **B. Poston.** 1993. Crop damage, autumn waterfowl populations and cereal grain harvests in the prairie provinces of western Canada. Wildfowl 44: 121–132.

Clark, R. G., K. L. Guyn, R. C. N. Penner, and **D. Semel.** 1996. Altering predator foraging behavior to reduce predation of ground-nesting birds. Transactions of the North American Wildlife and Natural Resources Conference 61: 118–126.

Clark, T. P., R. J. Norstrom, G. Fox, and **W. T. Won.** 1987. Dynamics of organochlorine compounds in Herring Gulls (*Larus argentatus*): II. A two compartment model with parameters for seven compounds. Environmental Toxicology and Chemistry 6: 547–559.

Clark, T., K. Clark, S. Paterson, R. J. Norstrom, and **D. Mackay.** 1988. Wildlife monitoring, modelling and fugacity. Environmental Science and Technology 22: 120–127.

Collins, B. T. 1987. Analysis of trends from Woodcock singing ground surveys 1969–85. Canadian Wildlife Service Progress Notes number 170. 5 pages.

Collins, B. T., and **A. J. Gaston.** 1987. Estimating the error involved in using egg density to predict laying dates. Journal of Field Ornithology 58: 464–473.

Colls, D. G. 1951. The conflict between waterfowl and agriculture. Transactions of the North American Wildlife Conference 16: 89–93.

Comba, M. E., R. J. Norstrom, C. R. Macdonald, and **K. E. Kaiser.** 1993. A Lake Ontario – Gulf of St. Lawrence dynamic mass balance for mirex. Environmental Science and Technology 27: 2198–2206.

Cooch, F. G. 1955. Observations on the autumn migration of Blue Geese. Wilson Bulletin 67: 171–174.

Cooch, F. G. 1961. Ecological aspects of the Blue-Snow Goose complex. Auk 78: 72–89.

Cooch, F. G. 1963. Recent changes in the distribution of colour phases of *Chen caerulescens caerulescens*. Proceedings International Ornithological Congress 13: 1182–1194.

Cooch, F. G. 1964. A preliminary study of the survival value of a functional salt gland in prairie Anatidae. Auk 81: 380–393.

Cooch, F. G. 1965. The breeding biology and management of the northern eider (*Somateria mollissima borealis*) in the Cape Dorset area, Northwest Territories. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 10. 68 pages.

Cooch, F. G. 1982. Factors influencing changes in origin, numbers, and distribution of non-resident, waterfowl hunters in Canada. Canadian Wildlife Service Progress Notes number 130. 16 pages.

Cooch, F. G. 1984. The kill of ducks and geese in Canada by non-resident hunters. Canadian Wildlife Service Progress Notes number 147. 15 pages.

Cooch, F. G. 1986. The current status of goose populations in Canada. Transactions of the North American Wildlife and Natural Resources Conference 51: 480–486.

Cooch, F. G. 1988. The impact of the Migratory Birds Convention Act and of seasonal phenology on recreational hunting of waterfowl in northwestern Canada. Canadian Wildlife Service Progress Notes number 173. 13 pages.

Cooch, F. G., and **J. Beardmore.** 1959. Assortative mating and reciprocal difference in the Blue – Snow Goose complex. Nature 183: 1833–1834.

Cooch, F. G., and **H. Boyd.** 1984. Changes in the net export of Mallard from western Canada and the contiguous US, 1972–82. Canadian Wildlife Service Progress Notes number 142. 27 pages.

Cooch, F. G., G. M. Stirrett, and **G. F. Boyer.** 1960. Autumn weights of Blue Geese (*Chen caerulescens*). Auk 77: 460–465.

Cooke, F., and **F. G. Cooch.** 1968. The genetics of polymorphism in the goose *Anser caerulescens*. Evolution 22: 289–300.

Cooper, C. R., A. P. Gilman, and **H. Blokpoel.** 1982. Ring-billed Gulls nesting on the Ottawa River near Ottawa. Ontario Field Biologist 36: 11–15.

Cottam, C., and **D. A. Munro.** 1954. Eelgrass status and environmental relations. Journal of Wildlife Management 18: 449–460.

Courtney, P. A., and **H. Blokpoel.** 1980. Food and indicators of food availability for common terns in the lower Great Lakes. Canadian Journal of Zoology 58: 1318–1323.

Courtney, P. A., and **H. Blokpoel.** 1983. Distribution and numbers of Common Terns on the lower Great Lakes during 1900–1980: a review. Colonial Waterbirds 6: 107–120.

Cowan, I. McT. 1947. The timber wolf in the Rocky Mountain National Parks of Canada. Canadian Journal of Research 25D: 139–174.

Cretney, W. J., D. R. Green, B. R. Fowler, B. Humphrey, F. R. Engelhardt, R. J. Norstrom, M. Simon, D. L. Feist, and **P. J. Boehm.** 1987. Hydrogeochemical setting of the Baffin Island oil spill experimental sites. III. Biota. Arctic 40 (Supplement 1): 71–79.

Cuerrier, J.-P., and **F. H. Schultz.** 1957. Studies of Lake Trout and Common Whitefish in Waterton Lakes, Waterton Lakes National Park, Alberta. Canadian Wildlife Service Wildlife Management Bulletin series 3, number 5. 41 pages.

Cuerrier, J.-P., J. A. Keith, and **E. Stone.** 1967. Problems with DDT in fish culture operations. Le Naturaliste canadien 94: 315–320.

Curtis, S. G., D. G. Dennis, and **H. Boyd.** *Editors.* 1985. Waterfowl studies in Ontario, 1973–81. Canadian Wildlife Service Occasional Paper number 54. 69 pages.

Dale, B. C., P. A. Martin, and **P. S. Taylor.** 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25: 616–626.

Dauphiné, T. C., Jr. 1971. Physical variables as an index to condition in barren-ground caribou. Transactions Northeast Section of the Wildlife Society 28: 91–108.

Dauphiné, T. C., Jr. 1975a. The disappearance of caribou reintroduced to Cape Breton Highlands National Park. Canadian Field-Naturalist 89: 299–310.

Dauphiné, T. C., Jr. 1975b. Kidney weight fluctuations affecting the kidney fat index in caribou. Journal of Wildlife Management 39: 379–386.

Dauphiné, T. C., Jr. 1976. Biology of the Kaminuriak Population of barren-ground caribou. Part 4: growth, reproduction and energy reserves. Canadian Wildlife Service Report Series number 38. 69 pages.

Dauphiné, T. C., Jr. 1978. Morphology of the barren-ground caribou ovary. Canadian Journal of Zoology 56: 1684–1696.

Dauphiné, T. C., Jr., and **R. L. McClure.** 1974. Synchronous mating in Canadian barren-ground caribou. Journal of Wildlife Management 38: 54–66.

Dawe, N. K., C. S. Runyan, and **R. McKelvey.** 1978. Seasonal food habits of the Barn Owl (*Tyto alba*) on the Alaksen National Wildlife Area, British Columbia. Canadian Field-Naturalist 92: 151–155.

De Forest, L. N., and **A. J. Gaston.** 1996. The effect of age on timing of breeding and reproductive success in the Thick-billed Murre. Ecology 77: 1501–1511.

Derocher, A. E., and **I. Stirling.** 1994. Age-specific reproductive performance of female polar bears. Journal of Zoology (London) 234: 527–536.

Derocher, A. E., and **I. Stirling.** 1995a. Estimation of polar bear population size and survival in western Hudson Bay. Journal of Wildlife Management 59: 215–221.

Derocher, A. E., and **I. Stirling.** 1995b. Temporal variation in reproduction and body mass of polar bears in western Hudson Bay. Canadian Journal of Zoology 73: 1657–1665.

Derocher, A. E., and **I. Stirling.** 1996. Aspects of survival in juvenile polar bears. Canadian Journal of Zoology 74: 1246–1252.

Derocher, A. E., I. Stirling, and **D. Andriashek.** 1992. Pregnancy rates and serum progesterone levels of polar bears in western Hudson Bay. Canadian Journal of Zoology 70: 561–566.

DesGranges, J.-L. 1978. Adaptive value of social behaviour in the Great Blue Heron (*Ardea herodias*). Pages 192–201 *in* Proceedings 1978 conference of Colonial Waterbird Group, Northern Illinois University Publication, DeKalb.

DesGranges, J.-L. 1979. Avian community structure in six forest stands in La Mauricie National Park, Quebec. Canadian Wildlife Service Occasional Paper number 41. 32 pages.

DesGranges, J.-L. 1982. Weight growth of young Double-crested Cormorants in the St. Lawrence estuary, Quebec. Colonial Waterbirds 5: 79–86.

DesGranges, J.-L., *Editor.* 1989. Studies of the effects of acidification of aquatic wildlife in Canada: Lacustrine birds and their habitats in Quebec. Canadian Wildlife Service Occasional Paper number 67. 68 pages.

DesGranges, J.-L., and **A. Reed.** 1981. Disturbance and control of selected colonies of Double-crested Cormorants in Quebec. Colonial Waterbirds 4: 12–19.

DesGranges, J.-L., and **M. Darveau.** 1985. Effect of lake acidity and morphometry on the distribution of aquatic birds in southern Quebec. Holarctic Ecology 8: 181–190.

DesGranges, J.-L., and **J. Rodrigue.** 1986. Influence of acidity and competition with fish on the development of ducklings in Quebec. Water Air and Soil Pollution 30: 743–750.

DesGranges, J.-L., and **M. L. Hunter.** 1987. Duckling response to lake acidification. Transactions of the North American Wildlife and Natural Resources Conference 52: 636–644.

DesGranges, J.-L., and **M. Darveau.** 1988. Fréquentation des lacs du Québec méridional par les oiseaux aquatiques à la période de reproduction. Le Naturaliste canadien 115: 1–7.

DesGranges, J.-L., P. Laporte, and **G. Chapdelaine.** 1979. First tour of inspection of Quebec heronries, 1977. Canadian Wildlife Service Progress Notes number 93. 4 pages. [other Progress Notes reported on later heron surveys in Quebec]

DesGranges, J.-L., G. Chapdelaine, and **P. Dupuis.** 1984. Sites de nidification et dynamique des populations du Cormoran à aigrettes au Québec. Canadian Journal of Zoology 62: 1260–1267.

DesGranges, J.-L., Y. Mauffette, and **G. Gagnon.** 1987. Sugar maple forest decline and implications for forest insects and birds. Transactions of the North American Wildlife and Natural Resources Conference 52: 677–689.

Diamond, A. W. 1991. Assessment of the risks from tropical deforestration [sic] to Canadian songbirds. Transactions of the North American Wildlife and Natural Resources Conference 56: 177–194.

Diamond, A. W., and **F. L. Filion.** *Editors.* 1987. The value of birds. International Council for Bird Preservation Technical Publication number 6.

Diamond, A. W., A. J. Gaston, and **R. G. B. Brown.** 1993. Studies of high-latitude seabirds. 3. A model of the energy demands of the seabirds of eastern and Arctic

Canada. *Edited by* W. A. Montevecchi. Canadian Wildlife Service Occasional Paper number 77. 36 pages.

Dickson, D. L. 1992. The Red-throated Loon as an indicator of environmental quality. Canadian Wildlife Service Occasional Paper number 73. 17 pages.

Dickson, D. L. 1993. Breeding biology of Red-throated Loons in the Canadian Beaufort Sea region. Arctic 46: 1–7.

Dickson, D. L. 1994. Nesting habitat of the Red-throated Loon, *Gavia stellata*, at Toker Point, Northwest Territories. Canadian Field-Naturalist 108: 10–16.

Dickson, D. L., *Editor.* 1997. King and Common eiders of the western Canadian Arctic. Canadian Wildlife Service Occasional Paper number 94. 73 pages.

Dickson, H. L., and **G. McKeating.** 1993. Wetland management for shorebirds and other species — experiences on the Canadian prairies. Transactions of the North American Wildlife and Natural Resources Conference 58: 370–377.

Dickson, K. M. 1989. Trends in sizes of breeding duck populations in western Canada, 1955–89. Canadian Wildlife Service Progress Notes number 186. 7 pages.

Dignard, N., R. Lalumière, A. Reed, and **M. Julien.** 1991. Habitats of the northeast coast of James Bay. Canadian Wildlife Service Occasional Paper number 70. 25 pages.

Dilworth, T. G., J. A. Keith, P. A. Pearce, and **L. M. Reynolds.** 1972. DDE and eggshell thickness in New Brunswick woodcock. Journal of Wildlife Management 36: 1186–1193.

Dilworth, T. G., P. A. Pearce, and **J. V. Dobell.** 1974. DDT in New Brunswick woodcocks. Journal of Wildlife Management 38: 331–337.

Dirschl, H. J. 1969. Foods of lesser scaup and blue–winged teal in the Saskatchewan River delta. Journal of Wildlife Management 33: 77–87.

Dirschl, H. J., and **D. L. Dabbs.** 1969. A contribution to the flora of the Saskatchewan River delta. Canadian Field-Naturalist 83: 212–228.

Dirschl, H. J., D. L. Dabbs, and **G. C. Gentle.** 1974. Landscape classification and plant successional trends in the Peace-Athabasca Delta. Canadian Wildlife Service Report Series number 30. 33 pages + map.

Dobell, J. V. 1972. Report on Woodcock harvests in Canada, 1967–1970, and composition of the kill in 1970. Canadian Wildlife Service Progress Notes number 27. 17 pages.

Dobell, J. V. 1977. Determination of woodcock habitat changes from aerial photography in New Brunswick. Proceedings Woodcock Symposium 6: 73–81.

Dobell, J. V., and **F. G. Cooch.** 1976. Report on the first Common Snipe wing surveys, 1974 and 1975, and results of some recent harvest surveys. Canadian Wildlife Service Progress Notes number 69. 5 pages.

Donald, D. B., and **A. H. Kooyman.** 1977. Migration and population dynamics of the Peace – Athabasca Delta goldeye population. Canadian Wildlife Service Occasional Paper number 31. 19 pages.

Downes, C. M., and **B. T. Collins.** 1996. The Canadian Breeding Bird Survey, 1966–1994. Canadian Wildlife Service Progress Notes number 210. 36 pages. [The latest in a series of progress reports, by various authors, the first published in 1970.]

Driver, E. A. 1977. Chironomid communities in small prairie ponds: some characteristics and controls. Freshwater Biology 7: 121–133.

Driver, E. A., and **D. C. Peden.** 1977. The chemistry of surface water in prairie ponds. Hydrobiologia 53: 33–48.

Driver, E. A., L. G. Sugden, and **R. J. Kovach.** 1974. Calorific, chemical and physical values of potential duck foods. Freshwater Biology 4: 281–292.

Drolet, C. A. 1976. Distribution and movements of white–tailed deer in southern New Brunswick in relation to environmental factors. Canadian Field-Naturalist 90: 123–136.

Drolet, C.-A. 1978. Use of forest clear-cuts by White-tailed Deer in southern New Brunswick and central Nova Scotia. Canadian Field-Naturalist 92: 275–282.

Drolet, C. A. 1986. Land claim settlements and the management of migratory birds, a case history: The James Bay and northern Quebec agreement. Transactions of the North American Wildlife and Natural Resources Conference 51: 511–515.

Drolet, C.-A., and **F. W. Anderka.** 1977. Distribution and movements of marked caribou in Ungava, July 1974 to July 1975. Canadian Wildlife Service Progress Notes number 77. 14 pages.

Drolet, C. A., A. Reed, M. Breton, and **F. Berkes.** 1987. Sharing wildlife management responsibilities with native groups: case histories in northern Quebec. Transactions of the North American Wildlife and Natural Resources Conference 52: 389–398.

Duncan, D., and **A. J. Gaston.** 1990. Movements of Ancient Murrelet broods at sea, after leaving their breeding colony. Studies in Avian Biology 14: 109–113.

Dunn, E. H. 1995. Bias in Christmas bird counts for species that visit feeders. Wilson Bulletin 107: 122–130.

Dzubin, A. 1955. Some evidence of home range in waterfowl. Transactions of the North American Wildlife Conference 20: 278–298.

Dzubin, A. 1959. Growth and plumage development of wild-trapped juvenile Canvasback (*Aythya valisineria*). Journal of Wildlife Management 23: 279–290.

Dzubin, A. 1965. A study of migrating Ross' Geese in western Saskatchewan. Condor 67: 511–534.

Dzubin, A. 1979. Recent increases of blue geese in western North America. Pages 141–175 *in* Proceedings Symposium "Biology and management of Pacific Flyway geese". *Edited by* R. L. Jarvis and J. C. Bartonek. Portland, Oregon.

Dzubin, A., and **H. Miller.** 1965. Regrouping of family members of the White-fronted Goose (*Anser albifrons*) after individual release. Bird-Banding 36: 184–191.

Dzubin, A., and **J. B. Gollop.** 1972. Aspects of Mallard breeding ecology in Canadian parkland and grassland. Pages 113–152 *in* Population ecology of migratory birds. Bureau of Sport Fisheries and Wildlife, Wildlife Research Report number 2.

Dzubin, A., H. Boyd, and **W. J. D. Stephen.** 1975. Blue and Snow Goose distribution in the Mississippi and Central Flyways 1951–71. Canadian Wildlife Service Progress Notes number 54. 34 pages.

Elliot, R. D., R. C. Ryan, and **W. W. Lidster.** 1990. The winter diet of Thick–billed Murres in coastal Newfoundland waters. Studies in Avian Biology 14: 125–138.

Elliott, J. E., and **J. L. Shutt.** 1993. Monitoring organochlorines in blood of Sharp-shinned Hawks (*Accipiter striatus*) migrating through the Great Lakes. Environmental Toxicology and Chemistry 12: 241–250.

Elliott, J. E., R. J. Norstrom, and **J. A. Keith.** 1988. Organochlorines and eggshell thinning in Northern Gannets (*Sula bassanus*) from eastern Canada, 1968–1984. Environmental Pollution 52: 82–102.

Elliott, J. E., R. W. Butler, R. J. Norstrom, and **P. E. Whitehead.** 1989. Environmental contaminants and reproductive success of Great Blue Herons *Ardea herodias* in British Columbia, 1986–87. Environmental Pollution 59: 91–114.

Elliott, J. E., D. G. Noble, R. J. Norstrom, and **P. E. Whitehead.** 1989. Organochlorine contamination in seabird eggs from the Pacific coast of Canada, 1971–1986. Environmental Monitoring and Assessment 12: 67–82.

Elliott, J. E., K. M. Langelier, A. M. Scheuhammer, P. H. Sinclair, and **P. E. Whitehead.** 1992. Incidence of lead poisoning in Bald Eagles and lead shot in waterfowl gizzards from British Columbia, 1988–91. Canadian Wildlife Service Progress Notes number 200. 7 pages.

Elliott, J. E., A. M. Scheuhammer, F. A. Leighton, and **P. A. Pearce.** 1992. Heavy metal and metallothionein concentrations in Atlantic Canadian seabirds. Archives of Environmental Contamination and Toxicology 22: 63–73.

Elliott, J. E., K. M. Langelier, P. Mineau, and **L. K. Wilson.** 1996. Poisoning of Bald Eagles and Red-tailed Hawks by carbofuran and fensulfothion in the lower Fraser Valley of British Columbia, Canada, 1989–90. Journal of Wildlife Diseases 32: 486–491.

Elliott, J. E., R. J. Norstrom, A. Lorenzen, S. E. Kennedy, H. Philibert, J. J. Stegeman, G. D. Bellward, L. E. Hart, and **K. M. Cheng.** 1996. Biological effects of polychlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls in Bald Eagle (*Haliaeetus leucocephalus*) chicks. Environmental Toxicology and Chemistry 15: 782–793.

Elliott, J. E., R. J. Norstrom, and **G. E. J. Smith.** 1996. Patterns, trends and toxicological significance of chlorinated hydrocarbon and mercury contaminants in Bald Eagle eggs from the Pacific coast of Canada. Archives of Environmental Contamination and Toxicology 31: 354–367.

Elliott, J. E., L. K. Wilson, K. W. Langelier, and **R. J. Norstrom.** 1996. Bald Eagle mortality and chlorinated hydrocarbon contaminants in livers from British Columbia, Canada, 1989–1994. Environmental Pollution 94: 9–18.

Elliott, J. E., L. K. Wilson, K. M. Langelier, P. Mineau, and **P. Sinclair.** 1996. Secondary poisoning of birds of prey by the organophosphorus insecticide, phorate. Ecotoxicology 5: 1–13.

Erskine, A. J. 1961. Nest-site tenacity and homing in the Bufflehead. Auk 78: 389–396.

Erskine, A. J. 1963. The Black-headed Gull in eastern North America. Audubon Field Notes 17: 334–338.

Erskine, A. J. 1964. Bird migration during April in southern British Columbia. Murrelet 45: 15–22.

Erskine, A. J. 1967. Range extension of Willets in eastern Canada. Canadian Field-Naturalist 81: 147–148.

Erskine, A. J. 1968a. Birds observed in north-central Alberta, summer 1964. Blue Jay 26: 24–31.

Erskine, A. J. 1968b. Encounters between Bald Eagles and other birds in winter. Auk 85: 681–683.

Erskine, A. J. 1971a. Growth, and annual cycles in weights, plumages, and reproductive organs, of Goosanders in eastern Canada. Ibis 113: 42–58.

Erskine, A. J. 1971b. Bird communities in and around Cape Breton wetlands. Canadian Field-Naturalist 85: 129–140.

Erskine, A. J. 1971c. Some new perspectives on the breeding ecology of Common Grackles. Wilson Bulletin 83: 352–370.

Erskine, A. J. 1971d. Fall migration of the Spotted Sandpiper. Ontario Bird Banding 7: 49–53.

Erskine, A. J. 1972a [incorrectly dated 1971 on copyright page; released 1972]. Buffleheads. Canadian Wildlife Service Monograph Series number 4. 240 pages.

Erskine, A. J. 1972b. Populations, movements and seasonal distribution of mergansers in northern Cape Breton Island. Canadian Wildlife Service Report Series number 17. 35 pages.

Erskine, A. J. 1972c. The Great Cormorants of eastern Canada. Canadian Wildlife Service Occasional Paper number 14. 21 pages.

Erskine, A. J. 1972d. Post-breeding assemblies of Ring-necked Ducks in eastern Nova Scotia. Auk 89: 449–450.

Erskine, A. J. 1974 [released 1975]. Problems associated with bird populations not adequately represented by the mapping census method. Acta Ornithologica XIV(24): 340–346.

Erskine, A. J. 1975. Winter birds of urban residential areas in eastern Ontario. Pages 18–31 *in* Nature and urban man, *Edited by* G. B. McKeating. Canadian Nature Federation Special Publication number 4.

Erskine, A. J. 1976. Chronology of nesting in urban birds as a guide to timing of censuses. American Birds 30: 667–672.

Erskine, A. J. 1977. Birds in boreal Canada: communities, densities and adaptations. Canadian Wildlife Service Report Series number 41. 71 pages.

Erskine, A. J. 1978. The first ten years of the co-operative Breeding Bird Survey in Canada. Canadian Wildlife Service Report Series number 42. 59 pages.

Erskine, A. J. 1979. Man's influence on potential nesting sites and populations of swallows in Canada. Canadian Field-Naturalist 93: 371–377.

Erskine, A. J. 1980a. Estimates of species populations from census and atlas data. Pages 254–263 *in* Proceedings VI International Conference of Bird Census Work & IV Meeting of European Ornithological Atlas Committee. *Edited by* H. Oelke.

Erskine, A. J. 1980b [released 1981]. Urban birds in the context of Canadian climate and settlement. Acta Congressus Internationalis Ornithologici 17: 1321–1326.

Erskine, A. J., *Editor*. 1987. Waterfowl breeding population surveys, Atlantic Provinces. Canadian Wildlife Service Occasional Paper number 60. 80 pages.

Erskine, A. J. 1988. The changing patterns of Brant migration in eastern North America. Journal of Field Ornithology 59: 110–119.

Erskine, A. J. 1990a. Joint laying in *Bucephala* ducks – "parasitism" or nest-site competition? Ornis Scandinavica 21: 52–56.

Erskine, A. J. 1990b. Half a million eiders off Cape Cod: Compounded errors or changed populations. Auk 107: 208–209.

Erskine, A. J. 1992a. Atlas of breeding birds of the Maritime Provinces. Nimbus Publications and Nova Scotia Museum. 270 pages.

Erskine, A. J. 1992b [released 1994]. A ten-year urban winter bird count in Sackville, New Brunswick. Canadian Field-Naturalist 106: 499–506.

Erskine, A. J. 1993 [released 1994]. Ring-billed Gull, *Larus delawarensis*, status and movements in the Maritime Provinces of Canada. Canadian Field-Naturalist 107: 46–52.

Erskine, A. J. 1997. Canada Goose studies in the Maritime Provinces 1950–1992 [editor, and sole or senior author

for 17 of 21 chapters]. Environment Canada-Atlantic Region Occasional Report number 7. 179 pages.
Erskine, A. J., and **W. D. McLaren.** 1972. Sapsucker nest holes and their use by other species. Canadian Field-Naturalist 86: 357–361.
Erskine, A. J., and **G. S. Davidson.** 1976 [released 1977]. Birds of the Fort Nelson lowlands of northeastern British Columbia. Syesis 9: 1–11.
Erskine, A. J., and **W. D. McLaren.** 1976. Comparative nesting biology of some hole-nesting birds in the Cariboo Parklands, British Columbia. Wilson Bulletin 88: 611–620.
Ewins, P. J. 1994. Pigeon Guillemot (*Cepphus columba*). *In*: The Birds of North America Number 49. *Edited by* A. Poole and F. Gill. Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania, and American Ornithologists' Union, Washington, D.C. 25 pages.
Ewins, P. J., and **C. S. Houston.** 1992. Recovery patterns of Ospreys, *Pandion haliaetus*, banded in Canada up to 1989. Canadian Field-Naturalist 106: 361–365.
Ewins, P. J., and **R. A. Andress.** 1995. The diet of Bald Eagles, *Haliaeetus leucocephalus*, wintering in the lower Great Lakes basin, 1987–1995. Canadian Field-Naturalist 109: 418–425.
Ewins, P. L., and **D. R. Bazely.** 1995. Phenology and breeding success of feral Rock Doves, *Columba livia*, in Toronto, Ontario. Canadian Field-Naturalist 109: 426–432.
Ewins, P. J., and **M. J. R. Miller.** 1995. Measurement error in aerial surveys of osprey productivity. Journal of Wildlife Management 59: 333–338.
Ewins, P. J., D. V. Weseloh, and **P. Mineau.** 1992. Geographical distribution of contaminants and productivity measures of Herring Gulls in the Great Lakes: Lake Huron 1980. Journal of Great Lakes Research 18: 316–330.
Ewins, P. J., D. V. Weseloh, J. H. Groom, R. Z. Dobos, and **P. Mineau.** 1994. The diet of Herring Gulls (*Larus argentatus*) during winter and early spring on the lower Great Lakes. Hydrobiologia 279/280: 39–55.
Ewins, P. J., D. V. (Chip) Weseloh, R. J. Norstrom, K. Legierse, H. J. Auman, and **J. P. Ludwig.** 1994. Caspian Terns on the Great Lakes: organochlorine contamination, reproduction, diet, and population changes, 1972–91. Canadian Wildlife Service Occasional Paper number 85. 28 pages.
Ewins, P. J., D. V. Weseloh, and **H. Blokpoel.** 1995. Within–season variation in nest numbers of Double-crested Cormorants (*Phalacrocorax auritus*) on the Great Lakes: implications for censusing. Colonial Waterbirds 18: 179–192.
Falardeau, G., and **J.-L. DesGranges.** 1991. Sélection de l'habitat et fluctuations récéntes des populations d'oiseaux des milieux agricoles du Québec. Canadian Field-Naturalist 105: 469–482.
Fetterolf, P. M., and **H. Blokpoel.** 1983. Reproductive performance of Caspian Terns at a new colony on Lake Ontario, 1979–1981. Journal of Field Ornithology 54: 170–186.
Fetterolf, P. M., H. Blokpoel, P. Mineau, and **G. Tessier.** 1984. Incidence, clustering, and egg fertility of larger than normal clutches in Great Lakes Ring-billed Gulls. Journal of Field Ornithology 55: 81–88.
Filion, F. L. 1978. Increasing the effectiveness of mail questionnaires. Wildlife Society Bulletin 6: 135–141.
Filion, F. L. 1980. Why do some purchasers of Migratory Game Bird Hunting Permits not hunt? Canadian Wildlife Service Progress Notes number 108. 7 pages.
Filion, F. L. 1981. Importance of question wording and response burden in hunter surveys. Journal of Wildlife Management 45: 873–882.
Filion, F. L., and **S. A. D. Parker.** 1984. Human dimensions of migratory game-bird hunting in Canada. Canadian Wildlife Service Occasional Paper number 51. 32 pages.
Filion, F. L., S. W. James, J.-L. Ducharme, W. Pepper, R. Reid, P. Boxall, and **D. Teillet.** 1983. The importance of wildlife to Canadians: highlights of the 1981 national survey. Canadian Wildlife Service, Ottawa.
Filion, F. L., E. DuWors, P. Boxall, P. Bouchard, R. Reid, P. Gray, A. Bath, A. Jacquemot, and **G. Legare.** 1993. The importance of wildlife to Canadians: highlights of the 1991 survey. Canadian Wildlife Service, Ottawa. 60 pages.
Filion, F. L., A. Jacquemot, F. DuWors, R. Reid, P. Boxall, P. Bouchard, and **A. Bath.** 1994. The importance of wildlife to Canadians: the economic significance of wildlife-related recreational activities in 1991. Canadian Wildlife Service, Ottawa. 46 pages.
Fimreite, N., R. W. Fyfe, and **J. A. Keith.** 1970. Mercury contamination of Canadian prairie seed-eaters and their avian predators. Canadian Field-Naturalist 84: 269–276.
Fimreite, N., W. N. Holsworth, J. A. Keith, P. A. Pearce, and **I. M. Gruchy.** 1971. Mercury in Canadian fish and fish-eating birds near sites of industrial contamination in Canada. Canadian Field-Naturalist 85: 211–220.
Finney, G. H. 1979. Some aspects of the native harvest of wildlife in Canada. Transactions of the North American Wildlife and Natural Resources Conference 44: 573–582.
Flemming, S. P., *Editor*. 1994. The 1991 international Piping Plover census in Canada. Canadian Wildlife Service Occasional Paper number 82. 57 pages.
Flook, D. R. 1970. Causes and implications of an observed sex differential in the survival of wapiti. Canadian Wildlife Service Report Series number 11. 71 pages.
Flook, D. R., and **J. E. Stenton.** 1969. Incidence and abundance of certain parasites in wapiti in the national parks of the Canadian Rockies. Canadian Journal of Zoology 47: 795–803.
Forbes, L. S. 1987. Feeding behaviour of Great Blue Herons at Creston, British Columbia. Canadian Journal of Zoology 65: 3062–3067.
Forbes, L. S., K. Simpson, J. P. Kelsall, and **D. R. Flook.** 1985. Reproductive success of Great Blue Herons in British Columbia. Canadian Journal of Zoology 63: 1110–1113.
Forsyth, D. J. 1989. Agricultural chemicals and prairie pothole wetlands: Meeting the needs of the resource and the farmer — Canadian perspective. Transactions of the North American Wildlife and Natural Resources Conference 54: 59–66.
Forsyth, D. J., and **P. A. Martin.** 1993. Effects of fenitrothion on survival behavior, and brain cholinesterase activity of white-throated sparrows (*Zonotrichia albicollis*). Environmental Toxicology and Chemistry 12: 92–103.
Forsyth, D. J., and **N. D. Westcott**. 1994. Carbofuran residues in grasshoppers and vegetation from aerially sprayed prairie pastures: potential effects on wildlife. Environmental Toxicology and Chemistry 13: 299–306.
Forsyth, D. J., C. F. Hinks, and **N. D. Westcott.** 1994. Feeding by clay-colored sparrows on grasshoppers and toxicity of carbofuran residues. Environmental Toxicology and Chemistry 13: 781–788.

Forsyth, D. J., P. A. Martin, K. D. De Smet, and **M. E. Riske.** 1994. Organochlorine contaminants and eggshell thinning in grebes from Prairie Canada. Environmental Pollution 85: 51–58.

Fowle, C. D. 1972. Effects of phosphamidon on forest birds in New Brunswick. Canadian Wildlife Service Report Series number 16. 22 pages.

Fox, G. A. 1993. What have biomarkers told us about the effects of contaminants on the health of fish-eating birds in the Great Lakes? The theory and a literature review. Journal of Great Lakes Research 19: 722–736.

Fox, G. A., and **T. Donald.** 1980. Organochlorine pollutants, nest defence behaviour, and reproductive success in Merlins. Condor 81: 81–84.

Fox, G. A., and **D. Boersma.** 1983. Characteristics of supernormal Ring-billed Gull clutches and their attending adults. Wilson Bulletin 95: 552–559.

Fox, G. A., A. P. Gilman, D. B. Peakall, and **F. W. Anderka.** 1978. Behavioral abnormalities of nesting Lake Ontario herring gulls. Journal of Wildlife Management 42: 477–483.

Fox, G. A., K. S. Yonge, and **S. G. Sealy.** 1980. Breeding performance, pollutant burden and eggshell thinning in Common Loons *Gavia immer* nesting on a boreal forest lake. Ornis Scandinavica 11: 243–248.

Fox, G. A., C. R. Cooper, and **J. P. Ryder.** 1981. Predicting the sex of Herring Gulls by using external measurements. Journal of Field Ornithology 52: 1–9.

Fox, G. A., S. W. Kennedy, R. J. Norstrom, and **D. C. Wigfield.** 1988. Porphyria in Herring Gulls: A biochemical response to chemical contamination of Great Lakes food chains. Environmental Toxicology and Chemistry 7: 831–839.

Fox, G. A., P. Mineau, B. Collins, and **P. C. James.** 1989. The impact of the insecticide carbofuran (Furadan 480F) on the Burrowing Owl in Canada. Canadian Wildlife Service Technical Report Series number 72. 25 pages. + addenda.

Fox, G. A., L. J. Allan, D. V. Weseloh, and **P. Mineau.** 1990. The diet of Herring Gulls during the nesting period in Canadian waters of the Great Lakes. Canadian Journal of Zoology 68: 1075–1085.

Fox, G. A., D. V. Weseloh, T. J. Kubiak, and **T. C. Erdtman.** 1991. Reproductive outcomes in colonial fish–eating birds: a biomarker for developmental toxicants in Great Lakes food chains. I. Historical and ecotoxicological perspectives. Journal of Great Lakes Research 17: 153–157.

Fox, G. A., B. Collins, E. Hayakawa, D. V. Weseloh, J. P. Ludwig, T. J. Kubiak, and **T. C. Erdtman.** 1991. Reproductive outcomes in colonial fish-eating birds: a biomarker for developmental toxicants in Great Lakes food chains. II. Spatial variation in the occurrence and prevalence of bill defects in young Double-crested Cormorants in the Great Lakes, 1979–1987. Journal of Great Lakes Research 17: 158–167.

Frank, R., P. Mineau, H. E. Braun, I. K. Barker, S. W. Kennedy, S. Trudeau. 1991. Deaths of Canada Geeese following spraying of turf with diazinon. Bulletin of Environmental Contamination and Toxicology 46: 852–858.

Freemark, K. E., and **C. Boutin.** 1994a. Impacts of agricultural herbicide use on terrestrial wildlife: A review for Canada. Canadian Wildlife Service Technical Report Series number 196. 53 pages.

Freemark, K. E., and **C. Boutin.** 1994b. Nontarget-plant risk assessment for pesticide registration in Canada. Environmental Management 18: 841–854.

Freemark, K. E., and **C. Boutin.** 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: A review with special reference to North America. Agriculture, Ecosystems and Environment 52: 67–91.

Fuller, W. A. 1951. Natural history and economic importance of the muskrat in the Athabasca – Peace Delta. Canadian Wildlife Service Wildlife Management Bulletin series 1, number 2.

Fuller, W. A. 1953. Aerial surveys for beaver in the Mackenzie District, Northwest Territories. Transactions of the North American Wildlife Conference 18: 329–336.

Fuller, W. A. 1959. The horns and teeth as indicators of age in bison. Journal of Wildlife Management 23: 342–344.

Fuller, W. A. 1960. Behaviour and social organization of the wild bison of Wood Buffalo National Park. Arctic 13: 3–19.

Fuller, W. A. 1961. The biology and management of the bison of Wood Buffalo National Park. Canadian Wildlife Service Wildlife Management Bulletin series 1, number 16. 52 pages.

Fyfe, R. W. 1976a. Rationale and success of the Canadian Wildlife Service peregrine breeding project. Canadian Field-Naturalist 90: 308–319.

Fyfe, R. W. 1976b. Status of Canadian raptor populations. Canadian Field-Naturalist 90: 370–375.

Fyfe, R. W., and **R. R. Olendorff.** 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service Occasional Paper number 23. 16 pages.

Fyfe, R. W., J. Campbell, B. Hayson, and **K. Hodson.** 1969. Regional population declines and organo-chlorine insecticides in Canadian Prairie Falcons. Canadian Field-Naturalist 83: 191–200.

Fyfe, R., S. A. Temple, and **T. J. Cade.** 1976. The North American Peregrine survey, 1975. Canadian Field-Naturalist 90: 228–273.

Fyfe, R. W., R. W. Risebrough, and **W. Walker II.** 1976. Pollutant effects on the reproduction of the Prairie Falcons and Merlins of the Canadian prairies. Canadian Field-Naturalist 90: 346–355.

Fyfe, R. W., U. Banasch, V. Benavides, N. Hilgert de Benavides, A. Luscombe, and **J. Sanchez.** 1990. Organochlorine residues in potential prey of Peregrine Falcons, *Falco peregrinus*, in Latin America. Canadian Field-Naturalist 104: 285–292.

Gamberg, M., and **A. M. Scheuhammer.** 1994. Cadmium in caribou and muskoxen from the Canadian Yukon and Northwest Territories. Science of the Total Environment 143: 221–234.

Gaston, A. J. 1982. Migration of juvenile Thick-billed Murres through Hudson Strait in 1980. Canadian Field-Naturalist 96: 30–34.

Gaston, A. J. 1985a. Energy invested in reproduction by Thick–billed Murres (*Uria lomvia*). Auk 102: 447–458.

Gaston, A. J. 1985b. The diet of Thick-billed Murre chicks in the eastern Arctic. Auk 102: 727–734.

Gaston, A. J. 1988a. The mystery of the murres: Thick–billed Murres, *Uria lomvia*, in the Great Lakes region, 1890–1986. Canadian Field-Naturalist 102: 705–711.

Gaston, A. J. 1988b. Timing of breeding of Kittiwakes *Rissa tridactyla* and growth and diet of the chicks at Hantzsch Island, N.W.T., Canada. Seabird 11: 3–11.

Gaston, A. J. 1990. Population parameters of the Ancient Murrelet. Condor 92: 998–1011.

Gaston, A. J. 1992. The Ancient Murrelet: a natural history in the Queen Charlotte Islands. Poyser, London. 249 pages.

Gaston, A. J. 1994. Status of the Ancient Murrelet, *Synthliboramphus antiquus*, in Canada and the effects of introduced predators. Canadian Field-Naturalist 108: 211–222.

Gaston, A. J. 1997. Mass and date at departure affect the survival of Ancient Murrelet *Synthliboramphus antiquus* chicks after leaving the colony. Ibis 139: 673–678.

Gaston, A. J., and **D. N. Nettleship.** 1981. The Thick-billed Murres of Prince Leopold Island: a study of the breeding ecology of a colonial high arctic seabird. Canadian Wildlife Service Monograph Series number 6, 349 pages.

Gaston, A. J., and **D. N. Nettleship.** 1982. Factors determining seasonal changes in attendance at colonies of the Thick-billed Murre *Uria lomvia*. Auk 99: 468–473.

Gaston, A. J., and **G. E. J. Smith.** 1984. The interpretation of aerial surveys for seabirds: some effects of behaviour. Canadian Wildlife Service Occasional Paper number 53. 18 pages.

Gaston, A. J., and **D. G. Noble.** 1985. The diet of thick-billed murres *Uria lomvia* in west Hudson Strait and northeast Hudson Bay. Canadian Journal of Zoology 63: 1148–1160.

Gaston, A. J., and **S. A. Smith.** 1987. Seabirds in the Cape Dyer – Reid Bay area of Cumberland Peninsula, Baffin Island, Northwest Territories. Canadian Field-Naturalist 101: 49–55.

Gaston, A. J., and **D. W. Powell.** 1989. Natural incubation, egg neglect and hatchability in the Ancient Murrelet. Auk 106: 433–438.

Gaston, A. J., and **I. L. Jones.** 1989. The relative importance of stress and programmed anorexia in determining mass loss by incubating Ancient Murrelets. Auk 106: 653–658.

Gaston, A. J., and **R. G. B. Brown.** 1991. Dynamics of seabird distributions in relation to variations in the availability of food on a landscape scale. Acta Congressus Internationalis Ornithologicus 20: 2306–2312.

Gaston, A. J., and **I. L. Jones.** 1991. Seabirds and marine mammals recorded in western Hecate Strait, British Columbia, in spring and early summer, 1984–1989. Canadian Field-Naturalist 105: 550–560.

Gaston, A. J., and **R. D. Elliot.** *Editors.* 1991. Studies of high-latitude seabirds. 2. Conservation biology of Thick-billed Murres in the northwest Atlantic. Canadian Wildlife Service Occasional Paper number 69. 61 pages.

Gaston, A. J., and **M. S. W. Bradstreet.** 1993. Intercolony differences in the summer diet of Thick-billed Murres in the eastern Canadian Arctic. Canadian Journal of Zoology 71: 1831–1840.

Gaston, A. J., and **G. Donaldson.** 1995. Peat deposits and Thick-billed Murre colonies in Hudson Strait and northern Hudson Bay: Clues to post-glacial colonization of the area by seabirds. Arctic 48: 354–358.

Gaston, A. J., and **R. D. Elliot.** 1996. Predation by Ravens *Corvus corax* on Brunnich's Guillemot *Uria lomvia* eggs and chicks and its possible impact on breeding site selection. Ibis 138: 742–748.

Gaston, A. J., and **M. Masselink.** 1997. The impact of Raccoons *Procyon lotor* on breeding seabirds at Englefield Bay, Haida Gwaii, Canada. Bird Conservation International 7: 35–52.

Gaston, A. J., G. Chapdelaine, and **D. G. Noble.** 1983. The growth of Thick-billed Murre chicks at colonies in Hudson Strait: inter- and intra-colony variation. Canadian Journal of Zoology 61: 2465–2475.

Gaston, A. J., D. G. Noble, and **M. A. Purdy.** 1983. Monitoring breeding biology parameters for murres *Uria* spp.: levels of accuracy and sources of bias. Journal of Field Ornithology 54: 275–282.

Gaston, A. J., R. I. Goudie, D. G. Noble, and **A. MacFarlane.** 1983. Observations on "turr" hunting in Newfoundland: age, body condition, and diet of Thick-billed Murres (*Uria lomvia*), and proportions of other seabirds, killed off Newfoundland in winter. Canadian Wildlife Service Progress Notes number 141. 7 pages.

Gaston, A. J., G. Chapdelaine, and **D. G. Noble.** 1984. Phenotypic variation among Thick-billed Murres from colonies in Hudson Strait. Arctic 37: 284–287.

Gaston, A. J., D. K. Cairns, R. D. Elliot, and **D. G. Noble.** 1985. A natural history of Digges Sound. Canadian Wildlife Service Report Series number 46. 61 pages.

Gaston, A. J., R. Decker, F. G. Cooch, and **A. Reed.** 1986. The distribution of larger species of birds breeding on the coasts of Foxe Basin and northern Hudson Bay. Arctic 39: 285–296.

Gaston, A. J., B. T. Collins, and **A. W. Diamond.** 1987. Estimating densities of birds at sea and the proportion in flight from counts made on transects of indefinite width. Canadian Wildlife Service Occasional Paper number 59. 14 pages.

Gaston, A. J., I. L. Jones, and **D. G. Noble.** 1988. Monitoring Ancient Murrelet breeding populations. Colonial Waterbirds 11: 58–66.

Gaston, A. J., H. R. Carter, and **S. G. Sealy.** 1993. Winter ecology and diet of Ancient Murrelets off Victoria, British Columbia. Canadian Journal of Zoology 71: 64–70.

Gaston, A. J., L. N. de Forest, G. Donaldson, and **D. G. Noble.** 1994. Population parameters of Thick-billed Murres at Coats Island, Northwest Territories, Canada. Condor 96: 935–948.

Gaston, A. J., L. N. de Forest, G. Gilchrist, and **D. N. Nettleship.** 1993. Monitoring Thick-billed Murre populations at colonies in northern Hudson Bay, 1972–92. Canadian Wildlife Service Occasional Paper number 80. 15 pages.

Gauthier, J., and **Y. Aubry.** *Editors.* 1996. The breeding birds of Québec: Atlas of the breeding birds of southern Québec. Association québécoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, Canadian Wildlife Service, Environment Canada, Québec Region, Montréal. 1302 pages.

Gauthier, M. C., H. Blokpoel, and **S. G. Curtis.** 1976. Observations on the spring migration of Snow Geese from southern Manitoba to James and Hudson Bays. Canadian Field-Naturalist 90: 196–199.

Gauvin, J., and **A. Reed.** 1987. A simulation model for the Greater Snow Goose population. Canadian Wildlife Service Occasional Paper number 64. 26 pages.

Gebauer, M. B., R. Z. Dobos, and **D. V. Weseloh.** 1993. Historical review of water bird populations and annotated list of water birds associated with Burlington Bay, Lake Ontario. Canadian Wildlife Service Occasional Paper number 78.

Gibbs, H. L., and **J. S. Tener.** 1958. On some helminth parasites collected from the musk ox (*Ovibos* *moschatus*) in the Thelon Game Sanctuary, Northwest Territories. Canadian Journal of Zoology 36: 529–532.

Gibson, G. G. 1968. Species composition of the genus *Streptocara* Railliet et al., 1912 and the occurrence of these avian nematodes (Acuariidae) on the Canadian Pacific coast. Canadian Journal of Zoology 46: 629–645.

Gibson, G. G. 1972. *Sciadiocara denticulata* n.sp. (Acuariidae) from *Actitis macularia* (L.) and other nematodes from spotted sandpiper and black-bellied plover. Canadian Journal of Zoology 50: 131–136.

Gibson, G. G. 1973. *Cardiofilaria pavlovskyi* Strom, 1937 and *Avioserpens* sp. (Nematoda) from Canadian ciconiiform birds. Canadian Journal of Zoology 51: 847–851.

Gibson, G. G., and **D. A. McKiel.** 1972. *Dracunculus insignis* (Leidy, 1858) and larval *Eustrongylides* sp. in a muskrat from Ontario, Canada. Canadian Journal of Zoology 50: 897–901.

Gibson, G. G., E. Broughton, and **L. P. E. Choquette.** 1972. Waterfowl mortality caused by *Cyathocotyle bushiensis* Khan, 1962 (Trematoda: Cyathocotylidae), St. Lawrence River, Quebec. Canadian Journal of Zoology 50: 1351–1356.

Gilbertson, M. 1974a. Pollutants in breeding Herring Gulls in the lower Great Lakes. Canadian Field-Naturalist 88: 273–280.

Gilbertson, M. 1974b. Seasonal changes in organochlorine compounds and mercury in Common Terns of Hamilton Harbour, Ontario. Bulletin of Environmental Contamination and Toxicology 12: 726–732.

Gilbertson, M., and **G. A. Fox.** 1977. Pollutant associated embryonic mortality of Great Lakes Herring Gulls. Environmental Pollution 12: 211–216.

Gilbertson, M., R. D. Morris, and **R. A. Hunter.** 1976. Incidence of abnormal chicks and residue levels of PCB in eggs of colonial bird species on the lower Great Lakes (1971–1973). Auk 93: 434–442.

Gilchrist, H. G., and **A. J. Gaston.** 1997a. Factors affecting the success of colony departure by Thick-billed Murre chicks. Condor 99: 345–352.

Gilchrist, H. G., and **A. J. Gaston.** 1997b. Effects of murre nest site characteristics and wind conditions on predation by glaucous gulls. Canadian Journal of Zoology 75: 518–524.

Gillespie, D. I., H. Boyd, and **P. Logan.** 1991. Wetlands for the world: Canada's Ramsar sites. Canadian Wildlife Service, Ottawa. 40 pages.

Gilman, A. P., G. A. Fox, D. B. Peakall, S. M. Teeple, T. R. Carroll, and **G. T. Haymes.** 1977. Reproductive parameters and egg contaminant levels of Great Lakes herring gulls. Journal of Wildlife Management 41: 458–468.

Gilman, A. P., D. J. Hallett, G. A. Fox, L. J. Allan, W. J. Learning, and **D. B. Peakall.** 1978. Effects of injected organochlorines on naturally incubated herring gull eggs. Journal of Wildlife Management 42: 484–493.

Gollop, J. B. 1956. The use of retrievers in banding flightless young Mallards. Transactions of the North American Wildlife Conference 21: 239–248.

Gollop, J. B. 1963. Autumnal distribution of young Mallards banded at Kindersley, Saskatchewan. Proceedings of the International Ornithological Congress 13: 855–865.

Gollop, J. B. 1965. Wetland inventories in western Canada. Transactions of the International Union of Game Biologists 6: 249–264.

Gollop, J. B., and **W. H. Marshall.** 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Committee. 14 pages.

Gollop, J. B., T. W. Barry, and **E. H. Iversen.** 1986. Eskimo Curlew. A vanishing species? Saskatchewan Natural History Society Special Publication number 17. 160 pages.

Goossen, J. P. 1990. Piping Plover research and conservation in Canada. Blue Jay 48: 139–153.

Goudie, R. I. 1981. Marine bird observations at Cape St. Mary's and Placentia and St. Mary's Bays, Newfoundland, winter 1978–79. Canadian Wildlife Service Progress Notes number 124. 10 pages.

Goudie, R. I. 1989. Historical status of Harlequin Ducks wintering in eastern North America – a reappraisal. Wilson Bulletin 101: 112–114.

Goudie, R. I., and **C. D. Ankney.** 1986. Body size, activity budgets, and diets of sea ducks wintering in Newfoundland. Ecology 67: 1475–1482.

Goudie, R. I., S. Brault, B. Conant, A. V. Kondratyev, M. R. Petersen, and **K. Vermeer.** 1994. The status of sea ducks in the north Pacific rim: Towards their conservation and management. Transactions of the North American Wildlife and Natural Resources Conference 59: 27–49.

Grasman, K. A., G. A. Fox, P. F. Scanlon, and **J. P. Ludwig.** 1996. Organochlorine-associated immunosuppression in prefledgling Caspian terns and herring gulls from the Great Lakes: an ecoepidemiological study. Environmental Health Perspectives 104 (Supplement 4): 829–842.

Gratto-Trevor, C. L., and **H. L. Dickson.** 1994. Confirmation of elliptical migration in a population of Semipalmated Sandpipers. Wilson Bulletin 106: 78–90.

Guyn, K. L., and **R. G. Clark.** 1997. Cover characteristics and success of natural and artificial duck nests. Journal of Field Ornithology 68: 33–41.

Hallett, D. J., R. J. Norstrom, F. I. Onuska, M. E. Comba, and **R. Sampson.** 1976. Mass spectral confirmation and analysis by the Hall detector of mirex and photomirex in Herring Gulls from Lake Ontario. Journal of Agricultural and Food Chemistry 24: 1189–1193.

Hallett, D. J., R. J. Norstrom, F. I. Onuska, and **M. Comba.** 1982. Chlorinated benzenes in Great Lakes Herring Gulls. Chemosphere 11: 277–285.

Harington, C. R. 1966. Extralimital occurrences of walruses in the Canadian Arctic. Journal of Mammalogy 47: 506–513.

Harington, C. R. 1968. Denning habits of the polar bear (*Ursus maritimus* Phipps). Canadian Wildlife Service Report Series number 5. 30 pages.

Harrington, B. A., and **R. I. G. Morrison.** 1979. Semipalmated Sandpiper migration in North America. Studies in Avian Biology 2: 83–100.

Haymes, G. T., and **H. Blokpoel.** 1978. Seasonal distribution and site tenacity of the Great Lakes Common Tern. Bird-Banding 49: 142–151.

Hebert, C. E., D. V. Weseloh, K. Kot, and **V. Glooschenko.** 1994. Organochlorine contaminants in a terrestrial foodweb on the Niagara Peninsula, Ontario, Canada 1987–89. Archives of Environmental Contamination and Toxicology 26: 356–366.

Hebert, C. E., R. J. Norstrom, M. Simon, B. M. Braune, D. V. Weseloh, and **C. R. Macdonald.** 1994. Temporal trends and sources of PCDDs and PCDFs in the Great Lakes: Herring Gull egg monitoring, 1981–1991. Environmental Science and Technology 28: 1266–1277.

Hebert, C. E., M. Gamberg, L. Mychasiw, B. T. Elkin, M. Simon, and **R. J. Norstrom.** 1996. Polychlorinated dibenzodioxins, dibenzofurans and non-ortho polychlorinated biphenyls in caribou (*Rangifer tarandus*) from the Canadian Arctic. Science of the Total Environment 185: 195–204.

Hebert, C. E., J. L. Shutt, and **R. J. Norstrom.** 1997. Dietary changes cause temporal fluctuations in polychlorinated biphenyl levels in Herring Gull eggs from Lake Ontario. Environmental Science and Technology 31: 1012–1017.

Hicklin, P. W. 1987. The migration of shorebirds in the Bay of Fundy. Wilson Bulletin 99: 540–570.

Hicklin, P. W., and **P. C. Smith.** 1984. Selection of foraging sites and invertebrate prey by migrant Semipalmated Sandpipers, *Calidris pusilla*, in Minas Basin, Bay of Fundy. Canadian Journal of Zoology 62: 2201–2210.

Hicklin, P. W., R. G. Hounsell, and **G. H. Finney.** 1989. Fundy pull trap: a new method of capturing shorebirds. Journal of Field Ornithology 60: 94–101.

Hitchcock, C. L., and **C. Gratto-Trevor.** 1997. Diagnosing a shorebird local population decline with a stage-structured population model. Ecology 78: 522–534.

Hobson, K. A. 1995. Reconstructing avian diets using stable-carbon and nitrogen isotope analysis of egg components: patterns of isotopic fractionation and turnover. Condor 97: 752–762.

Hobson, K. A. 1997. Pelagic Cormorant (*Phalacrocorax pelagicus*). *In* The Birds of North America. Number 282. *Edited by* A. Poole and F. Gill. Academy Natural Sciences, Philadelphia, & American Ornithologists' Union, Washington, D.C.

Hobson, K. A., and **R. G. Clark.** 1992a. Assessing avian diets using stable isotopes I: Turnover of ^{13}C in tissues. Condor 94: 181–188.

Hobson, K. A., and **R. G. Clark.** 1992b. Assessing avian diets using stable isotopes II: Factors influencing diet-tissue fractionation. Condor 94: 189–197.

Hobson, K. A., R. T. Alisauskas, and **R. G. Clark.** 1993. Stable–nitrogen isotope enrichment in avian tissues due to fasting and nutritional stress: implications for isotopic analyses of diet. Condor 95: 388–394.

Hobson, K. A., J. Piatt, and **J. Pitochelli.** 1994. Using stable isotopes to determine seabird trophic relationships. Journal of Animal Ecology 63: 786–798.

Hobson, K. A., K. D. Hughes, and **P. J. Ewins.** 1997. Using stable–isotope analysis to identify endogenous and exogenous sources of nutrients in eggs of migratory birds: Applications to Great Lakes contaminants research. Auk 114: 467–478.

Hochbaum, G. S., and **F. D. Caswell.** 1978. A forecast of long–term trends in breeding Mallard populations on the Canadian prairies. Canadian Wildlife Service Progress Notes number 90. 8 pages.

Hochbaum, G. S., and **C. J. Walters.** 1984. Components of hunting mortality in ducks: a management analysis. Canadian Wildlife Service Occasional Paper number 52. 28 pages.

Hochbaum, G. S., and **F. D. Caswell.** 1991. The relationship between delayed primary wing feather moult and local harvest rates of adult female Mallards in Manitoba, 1982–1984. Canadian Wildlife Service Progress Notes number 195. 3 pages.

Hochbaum, G. S., F. D. Caswell, B. C. Turner, and **D. J. Nieman.** 1987. Relationships among social components of duck breeding populations, production and habitat conditions in prairie Canada. Transactions of the North American Wildlife and Natural Resources Conference 52: 310–319.

Holroyd, G. L. 1995. Conservation of prairie raptors. Transactions of the North American Wildlife and Natural Resources Conference 60: 173–180.

Holroyd, G. L., and **U. Banasch.** 1990. The reintroduction of the Peregrine Falcon, *Falco peregrinus anatum*, into southern Canada. Canadian Field-Naturalist 104: 203–208.

Howell, G., and **J. Kerekes.** 1982. Ectogenic meromyxia at Layton's Lake, Nova Scotia, Canada. Journal of Freshwater Ecology 1: 483–493.

Howell, G., and **J. Kerekes.** 1987. Primary production of two small lakes in Atlantic Canada. Proceedings Nova Scotia Institute of Science 37: 71–88.

Hyslop, C., and **S. Wendt.** 1982. Kill of Greater Snow Geese in Quebec, 1978–80. Canadian Wildlife Service Progress Notes, number 128. 9 pages.

James, P. C., and **G. A. Fox.** 1987. Effects of some insecticides on productivity of burrowing owls. Blue Jay 45: 65–71.

Jarman, W. M., M. Simon, R. J. Norstrom, S. A. Burns, C. A. Bacon, B. R. T. Simoneit, and **R. W. Risebrough.** 1992. Global distribution of tris(4-chlorophenyl)methanol in high trophic level birds and mammals. Environmental Science and Technology 26: 1770–1774.

Jarman, W. M., R. J. Norstrom, D. C. G. Muir, B. Rosenburg, M. Simon, and **R. W. Baird.** 1996. Levels of organochlorine compounds, including PCDDs and PCDFs, in blubber of cetaceans from the west coast of North America. Marine Pollution Bulletin 32: 426–436.

Jobin, B., J.-L. DesGranges, and **C. Boutin.** 1996. Comparison of the BBS and intensive surveys at selected BBS stops. Bird Populations 3: 14–25.

Jobin, B., J.-L. DesGranges, and **C. Boutin.** 1996. Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. Agriculture, Ecosystems and Environments 57: 103–116.

Johns, B. W. 1993. The influence of grove size on bird species richness in aspen parklands. Wilson Bulletin 105: 256–264.

Jones, I. L., A. J. Gaston, and **J. B. Falls.** 1987. Colony departure of family groups of Ancient Murrelets. Condor 89: 940–943.

Jones, I. L., A. J. Gaston, and **J. B. Falls.** 1990. Factors affecting colony attendance by Ancient Murrelets (*Synthliboramphus antiquus*). Canadian Journal of Zoology 68: 433–441.

Jonkel, C. J., D. R. Gray, and **B. Hubert.** 1975. Immobilizing and marking wild muskoxen in arctic Canada. Journal of Wildlife Management 39: 112–117.

Jonkel, C., P. Smith, I. Stirling, and **G. B. Kolenosky.** 1976. The present status of the polar bear in the James Bay and Belcher Islands area. Canadian Wildlife Service Occasional Paper number 26. 40 pages.

Jonkel, C., E. Land, and **R. Redhead.** 1978. The productivity of polar bears (*Ursus maritimus*) in the southeastern Baffin Island area, Northwest Territories. Canadian Wildlife Service Progress Notes number 91. 7 pages.

Kaiser, G. W., A. E. Derocher, S. Crawford, M. J. Gill, and **I. A. Manley.** 1995. A capture technique for Marbled Murrelets in coastal inlets. Journal of Field Ornithology 66: 321–333.

Keith, J. A. 1969. Guest Editorial. The DDE affair. Canadian Field-Naturalist 83: 89–90.

Keith, J. A. 1995. Management policies for cormorants in Canada. Pages 234–237 *in* The Double-crested Cormorant: Biology, conservation and management. *Edited by* D. N. Nettleship, D. C. Duffy. Colonial Waterbirds 18 (Special Publication 1).

Keith, J. A., and **I. M. Gruchy.** 1972. Residue levels of chemical pollutants in North American birdlife. Proceedings International Ornithological Congress 15: 437–454.

Kelsall, J. P. 1950. A study of bird populations in the apple orchards of the Annapolis Valley, Nova Scotia. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 1. 69 pages.

Kelsall, J. P. 1955. Barren–ground caribou movements in the Canadian Arctic. Transactions of the North American Wildlife Conference 20: 551–560.

Kelsall, J. P. 1968. The migratory barren-ground caribou of Canada. Canadian Wildlife Service Monograph Series number 3, 340 pages + 24 maps. [included content of earlier Wildlife Management Bulletins by same and other authors]

Kelsall, J. P. 1969. Structural adaptations of moose and deer for snow. Journal of Mammalogy 50: 302–310.

Kelsall, J. P. 1970. Chemical elements in waterfowl flight feathers. Canadian Wildlife Service Progress Notes number 17. 11 pages.

Kelsall, J. P. 1974. Snow goose primaries as indicators of age and sex. Canadian Journal of Zoology 52: 791–794.

Kelsall, J. P., and **W. Prescott.** 1971. Moose and deer behaviour in snow in Fundy National Park, New Brunswick. Canadian Wildlife Service Report Series number 15. 25 pages.

Kelsall, J. P., and **J. R. Calaprice.** 1972. Chemical content of waterfowl plumage as a potential diagnostic tool. Journal of Wildlife Management 36: 1088–1097.

Kelsall, J. P., and **E. S. Telfer.** 1974. Biogeography of moose with particular reference to western North America. Le Naturaliste canadien 101: 117–130.

Kelsall, J. P., and **W. J. Pannekoek.** 1976. The mineral profile of plumage in captive lesser snow geese. Canadian Journal of Zoology 54: 301–305.

Kelsall, J. P., and **R. Burton.** 1977. Identification of origins of lesser snow geese by X–ray spectrometry. Canadian Journal of Zoology 55: 718–732.

Kelsall, J. P., and **R. Burton.** 1979. Some problems in identification of origins of lesser snow geese by chemical profiles. Canadian Journal of Zoology 57: 2292–2302.

Kelsall, J. P., and **D. R. Klein.** 1979. The state of knowledge of the Porcupine caribou herd. Transactions of the North American Wildlife and Natural Resources Conference 44: 508–521.

Kelsall, J. P., and **K. Simpson.** 1980. A three-year study of the Great Blue Heron in southwestern British Columbia. Proceedings Colonial Waterbird Group (1979) 3: 69–74.

Kelsall, J. P., W. J. Pannekoek, and **R. Burton.** 1975a. Chemical variability in plumage of wild lesser snow geese. Canadian Journal of Zoology 53: 1369–1375.

Kelsall, J. P., W. J. Pannekoek, and **R. Burton.** 1975b. Variability in the chemical content of waterfowl plumage. Canadian Journal of Zoology 53: 1379–1386.

Kelsall, J. P., E. S. Telfer, and **T. D. Wright.** 1977. The effects of fire on the ecology of the Boreal Forest, with particular reference to the Canadian north: a review and selected bibliography. Canadian Wildlife Service Occasional Paper number 32. 56 pages.

Kennedy, S. W., and **G. A. Fox.** 1990. Highly carboxylated porphyrins as a biomarker of polyhalogenated aromatic hydrocarbon exposure in wildlife: Confirmation of their presence in Great Lakes herring gull chicks in the early 1970s and important methodological details. Chemosphere 21: 407–415.

Kerbes, R. H. 1975. The nesting population of Lesser Snow Geese in the eastern Canadian Arctic: a photographic inventory of June 1973. Canadian Wildlife Service Report Series number 35. 46 pages.

Kerbes, R. H. 1982. Lesser Snow Geese and their habitat on west Hudson Bay. Le Naturaliste canadien 109: 905–911.

Kerbes, R. H. 1983. Lesser Snow Goose colonies in the western Canadian Arctic. Journal of Wildlife Management 47: 523–526.

Kerbes, R. H. 1994. Colonies and numbers of Ross' Geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary. Canadian Wildlife Service Occasional Paper number 81. 45 pages.

Kerbes, R. H., M. R. McLandress, G. E. J. Smith, G. W. Beyersbergen, and **B. Godwin.** 1983. Ross' Goose and Lesser Snow Goose colonies in the central Canadian Arctic. Canadian Journal of Zoology 61: 168–173.

Kerbes, R. H., P. M. Kotanen, and **R. L. Jefferies.** 1990. Destruction of wetland habitats by Lesser Snow Geese: a keystone species on the west coast of Hudson Bay. Journal of Applied Ecology 27: 242–258.

Kerekes, J. 1974. Limnological conditions in five small oligotrophic lakes in Terra Nova National Park, Nfld. Journal of the Fisheries Research Board of Canada 31: 555–583.

Kerekes, J. 1975. Phosphorus supply in undisturbed lakes in Kejimkujik National Park, Nova Scotia. Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie 19: 349–357.

Kerekes, J. 1983. Predicting trophic response to phosphorus addition in a Cape Breton lake. Proceedings Nova Scotia Institute of Science 33: 7–18.

Kerekes, J. 1990. Possible correlation of Common Loon population with the trophic state of a water body. Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie 24: 349–353.

Kerekes, J., and **B. Pollard.** *Editors.* Proceedings of Symposium "Aquatic birds in the trophic web of lakes". Hydrobiologia 279/280 (special issue). 524 pages.

Kerekes, J., G. Howell, S. Beauchamp, and **T. Pollock.** 1982. Characterization of three lake basins sensitive to acid precipitation in central Nova Scotia (June 1979 to May 1980). Internationale Revue der gesamten Hydrobiologie 67: 679–694.

Kerekes, J., B. Freedman, G. Howell, and **P. Clifford.** 1984. Comparison of the characteristics of an acidic eutrophic, and an acidic oligotrophic lake near Halifax. Water Pollution Research Journal of Canada 19: 1–10.

Kerekes, J., S. Beauchamp, R. Tordon, and **T. Pollock.** 1986. Sources of sulphate and acidity in wetlands and lakes in Nova Scotia. Water Air and Soil Pollution 31: 207–214.

Kerekes, J., S. Beauchamp, R. Tordon, and **C. Tremblay.** 1986. Organic versus anthropogenic acidity in tributaries of the Kejimkujik watersheds in western Nova Scotia. Water Air and Soil Pollution 31: 165–173.

Kerekes, J., B. Freedman, S. Beauchamp, and **R. Tordon.** 1989. Physical and chemical characteristics of three acidic, oligotrophic lakes and their watersheds in Kejimkujik National Park, Nova Scotia. Water Air and Soil Pollution 46: 99–118.

Kerekes, J., A. Blouin, and **S. Beauchamp.** 1990. Trophic response to phosphorous [sic] in acidic and non-acidic lakes in Nova Scotia, Canada. Hydrobiologia 191: 105–110.

Kiel, W. H., Jr., A. S. Hawkins, and **N. G. Perret.** 1972. Waterfowl habitat trends in the aspen parkland of Manitoba. Canadian Wildlife Service Report Series number 18. 61 pages.

Kiliaan, H. P. L., and **I. Stirling.** 1978. Observations on overwintering walruses in the eastern Canadian High Arctic. Journal of Mammalogy 59: 197–200.

Kiliaan, H. P. L., I. Stirling, and **C. Jonkel.** 1978. Polar bears in the area of Jones Sound – Norwegian Bay. Canadian Wildlife Service Progress Notes number 88. 21 pages.

Kingsley, M. C. S. 1979. Fitting the von Bertalanffy growth equation to polar bear age – weight data. Canadian Journal of Zoology 57: 1020–1025.

Kirk, D. A., A. W. Diamond, K. A. Hobson, and **A. R. Smith.** 1996. Breeding bird communities of the western and northern Canadian boreal forest: relationship to forest type. Canadian Journal of Zoology 74: 1749–1770 [& Erratum: Canadian Journal of Zoology 75: 157–159].

Kirk, D. A., A. W. Diamond, A. R. Smith, G. E. Holland, and **P. Chytyk.** 1997. Population changes in boreal forest birds in Saskatchewan and Manitoba. Wilson Bulletin 109: 1–27.

Kirkham, I. R., and **D. N. Nettleship.** 1987. Status of the Roseate Tern in Canada. Journal of Field Ornithology 58: 505–515.

Knapton, R. W., and **P. Mineau.** 1995. Effects of granular formulations of terbufos and fonofos applied to cornfields on mortality and reproductive success of songbirds. Ecotoxicology 4: 137–152.

Kress, S. W., and **D. N. Nettleship.** 1988. Re-establishment of Atlantic Puffins (*Fratercula arctica*) at a former breeding site in the Gulf of Maine. Journal of Field Ornithology 59: 161–170.

Kuyt, E. 1966. Further observations of large Canada Geese moulting on the Thelon River, Northwest Territories. Canadian Field-Naturalist 80: 63–69.

Kuyt, E. 1972. Food habits and ecology of wolves on barren-ground caribou range in the Northwest Territories. Canadian Wildlife Service Report Series number 21. 36 pages.

Kuyt, E. 1980. Distribution and breeding biology of raptors in the Thelon River area, Northwest Territories, 1957–1969. Canadian Field-Naturalist 94: 121–130.

Kuyt, E. 1992. Aerial radio–tracking of Whooping Cranes migrating between Wood Buffalo National Park and Aransas National Wildlife Refuge, 1981–84. Canadian Wildlife Service Occasional Paper number 74. 50 pages.

Kuyt, E. 1993. Whooping Crane, *Grus americana*, home range and breeding range expansion in Wood Buffalo National Park, 1970–1991. Canadian Field-Naturalist 107: 1–12.

Kuyt, E. 1995. The nest and eggs of the Whooping Crane, *Grus americana*. Canadian Field-Naturalist 109: 1–5.

Kuyt, E. 1996. Reproductive manipulation in the Whooping Crane *Grus americana*. Bird Conservation International 6: 3–10.

Kuyt, E., and **B. W. Johns.** 1992. Recent American Avocet, *Recurvirostra americana*, breeding records in the Northwest Territories, with notes on avocet parasitism of Mew Gull, *Larus canus*, nests. Canadian Field-Naturalist 106: 507–510.

Langford, W. A., and **D. J. Cocheba.** 1978. The wildlife valuation problem: a critical review of economic approaches. Canadian Wildlife Service Occasional Paper number 37. 35 pages.

L'Arrivée, L. P., and **H. Blokpoel.** 1990. Seasonal distribution and site tenacity of Black-crowned Night-Herons, *Nycticorax nycticorax*, banded in Canada. Canadian Field-Naturalist 104: 534–539.

Lehoux, D., A. Bourget, P. Dupuis, and **J. Rosa.** 1985. La sauvagine dans le système du Saint-Laurent. Service canadien de la faune, Région du Québec. 2 volumes. 76 + 73 pages.

Lemieux, L. 1959a. The breeding biology of the Greater Snow Goose on Bylot Island, Northwest Territories. Canadian Field-Naturalist 73: 117–128.

Lemieux, L. 1959b. Histoire naturelle et aménagement de la Grande Oie blanche (*Chen hyperborea atlantica*). Le Naturaliste canadien 86: 133–192.

Lemieux, L., and **G. Moisan.** 1959. The migration, mortality rate and recovery rate of the Quebec Black Duck. Transactions Northeast Wildlife Conference 10: 124–148.

Lesage, L., A. Reed, and **J.-P. L. Savard.** 1997. Plumage developement [sic] and growth of wild Surf Scoter *Melanitta perspicillata* ducklings. Wildfowl 47: 198–203.

Lévesque, H., B. Collins, and **A. M. Legris.** 1993. Migratory game birds harvested in Canada during the 1991 hunting season. Canadian Wildlife Service Progress Notes number 204. 42 pages. [The latest in a series of annual progress reports, by various authors, starting in 1968. Similar information was presented in several separate annual Progress Notes in early years.]

Lock, A. R. 1987. Recent increases in the breeding population of Black-legged Kittiwakes, *Rissa tridactyla*, in Nova Scotia. Canadian Field-Naturalist 101: 331–334.

Lock, A. R. 1988. Recent increases in the breeding population of Ring-billed Gulls, *Larus delawarensis*, in Atlantic Canada. Canadian Field-Naturalist 102: 627–633.

Lock, A. R., and **F. W. Anderka.** 1985. The use of radioactive tags in monitoring the reproductive success of terns. Journal of Field Ornithology 56: 388–393.

Longcore, J. R., R. K. Ross, and **K. L. Fis[c]her.** 1987. Wildlife resources at risk through acidification of wetlands. Transactions of the North American Wildlife and Natural Resources Conference 52: 608–618.

Loughrey, A. G. 1959. Preliminary investigation of the Atlantic walrus. Canadian Wildlife Service Wildlife Management Bulletin series 1, number 14. 123 pages.

Macpherson, A. H. 1961. Observations on Canadian Arctic *Larus* gulls, and on the taxonomy of *L. thayeri* Brooks. Arctic Institute of North America Technical Paper number 7. 40 pages.

Macpherson, A. H. 1965. The origin of diversity in mammals of the Canadian arctic tundra. Systematic Zoology 14: 153–173.

Macpherson, A. H. 1966. The abundance of lemmings at Aberdeen Lake, District of Keewatin, 1959–63. Canadian Field-Naturalist 80: 89–94.

Macpherson, A. H. 1969. The dynamics of Canadian arctic fox populations. Canadian Wildlife Service Report Series number 8. 52 pages.

Macpherson, A. H., and **S. D. MacDonald.** 1962. Breeding places of the Ivory Gull in arctic Canada. National Museum of Canada Bulletin 183: 111–117.

Macpherson, A. H., and **M. A. Gibson.** 1965. The structure and function of the cheek pads of the brown lemming, *Lemmus sibiricus trimucronatus* (Kerr). Canadian Journal of Zoology 43: 613–617.

Macpherson, A. H., C. R. Harington, and **J. P. Kelsall.** 1962. The barren-ground grizzly bear in northern Canada. Arctic 15: 294–298.

Maisonneuve, C., P. Brousseau, and **D. Lehoux.** 1990. Critical fall staging sites of shorebirds migrating through the St. Lawrence system, Quebec. Canadian Field-Naturalist 104: 372–378.

Maltby, L. S. 1978. Birds of the coastal zone of Melville Island, 1973–75. Canadian Field-Naturalist 92: 24–29.

Maltby–Prevett, L. S., H. Boyd, and **J. D. Heyland.** 1975. Observation in Iceland and northwest Europe of Brant from the Queen Elizabeth Islands, N.W.T., Canada. Bird–Banding 46: 155–161.

Martell, A. M. 1979. Selection of conifer seeds by deer mice and red-backed voles. Canadian Journal of Forest Research 9: 201–204.

Martell, A. M. 1981. Food habits of Southern Red–backed Voles (*Clethrionomys gapperi*) in northern Ontario. Canadian Field-Naturalist 95: 325–328.

Martell, A. M. 1983a. Demography of southern red–backed voles (*Clethrionomys gapperi*) and deer mice (*Peromyscus maniculatus*) after logging in north-central Ontario. Canadian Journal of Zoology 61: 958–969.

Martell, A. M. 1983b. Changes in small mammal communities after logging in north-central Ontario. Canadian Journal of Zoology 61: 970–980.

Martell, A. M. 1984. Changes in small mammal communities after fire in northcentral Ontario. Canadian Field-Naturalist 98: 223–226.

Martell, A. M., and **A. M. Pearson.** 1978. The small mammals of the Mackenzie delta region, Northwest Territories, Canada. Arctic 31: 475–488.

Martell, A. M., and **A. L. Macaulay.** 1981. Food habits of Deer Mice (*Peromyscus maniculatus*) in northern Ontario. Canadian Field-Naturalist 95: 319–324.

Martell, A. M., and **R. J. Milko.** 1986. Seasonal diets of Vancouver Island Marmots, *Marmota vancouverensis*. Canadian Field-Naturalist 100: 241–245.

Martin, P. A., D. V. Weseloh, C. A. Bishop, K. Legierse, B. Braune, and **R. J. Norstrom.** 1995. Organochlorine contaminants in avian wildlife of Severn Sound. Water Quality Research Journal of Canada 30: 693–711.

McArthur, M. L. B., G. A. Fox, D. B. Peakall, and **B. J. R. Philogene.** 1983. Ecological significance of behavioral and hormonal abnormalities in breeding ring doves fed an organochlorine chemical mixture. Archives of Environmental Contamination and Toxicology 12: 343–353.

McCormick, K. J. 1986. A survey of Trumpeter Swans in the South Nahanni River area, NWT. Canadian Wildlife Service Progress Notes number 158. 5 pages.

McCracken, J. D., M. S. W. Bradstreet, and **G. L. Holroyd.** 1981. Breeding birds of Long Point, Lake Erie: a study in community succession. Canadian Wildlife Service Report Series number 44. 72 pages.

McCullough, G. B. 1981. Migrant waterfowl utilization of the Lake Erie shore, Ontario, in the vicinity of the Nanticoke Industrial Development. Journal of Great Lakes Research 7: 117–122.

McEwan, E. H. 1957. Birds observed at Bathurst Inlet, Northwest Territories. Canadian Field-Naturalist 71: 109–115.

McEwan, E. H. 1958. Observations on the Lesser Snow Goose nesting grounds, Egg River, Banks Island. Canadian Field-Naturalist 72: 122–127.

McEwan, E. H. 1963. Seasonal annuli in the cementum of the teeth of barren-ground caribou. Canadian Journal of Zoology 41: 111–113.

McEwan, E. H. 1968a. Growth and development of the barren-ground caribou. II. Postnatal growth rates. Canadian Journal of Zoology 46: 1023–1029.

McEwan, E. H. 1968b. Hematological studies of barren-ground caribou. Canadian Journal of Zoology 46: 1031–1036.

McEwan, E. H., and **A. J. Wood.** 1966. Growth and development of the barren-ground caribou: 1. Heart girth, hind foot length, and body weight relationships. Canadian Journal of Zoology 44: 401–411.

McEwan, E. H., and **P. E. Whitehead.** 1969. Changes in the blood constituents of reindeer and caribou occurring with age. Canadian Journal of Zoology 47: 557–562.

McEwan, E. H., and **P. E. Whitehead.** 1970. Seasonal changes in the energy and nitrogen intake in reindeer and caribou. Canadian Journal of Zoology 48: 905–913.

McEwan, E. H., and **P. E. Whitehead.** 1971. Measurement of the milk intake of reindeer and caribou calves using tritiated water. Canadian Journal of Zoology 49: 443–447.

McEwan, E. H., and **P. E. Whitehead.** 1972. Reproduction in female reindeer and caribou. Canadian Journal of Zoology 50: 43–46.

McEwan, E. H., and **A. F. C. Koelink.** 1973. The heat production of oiled mallards and scaup. Canadian Journal of Zoology 51: 27–31.

McEwan, E. H., and **P. M. Whitehead.** 1980. Uptake and clearance of petroleum hydrocarbons by the glaucous-winged gull (*Larus glaucescens*) and the mallard duck (*Anas platyrhynchos*). Canadian Journal of Zoology 58: 723–726.

McEwan, E. H., and **P. M. Whitehead.** 1984. Seasonal changes in body weight and composition of dunlin (*Calidris alpina*). Canadian Journal of Zoology 62: 154–156.

McEwan, E. H., A. J. Wood, and **H. C. Norden.** 1965. Body temperature of barren-ground caribou. Canadian Journal of Zoology 43: 683–687.

McEwan, E. H., N. Aitchison, and **P. E. Whitehead.** 1974. Energy metabolism of oiled muskrats. Canadian Journal of Zoology 52: 1057–1062.

McEwan, E. H., P. Whitehead, R. G. White, and **J. O. Anvik.** 1976. Effect of digestible energy intake on glucose synthesis in reindeer and caribou. Canadian Journal of Zoology 54: 737–751.

McKelvey, R. W., and **N. A. M. Verbeek.** 1988. Habitat use, behaviour, and management of Trumpeter Swans, *Cygnus buccinator*, wintering at Comox, British Columbia. Canadian Field-Naturalist 102: 434–441.

McKelvey, R. W., M. C. Dennington, and **D. Mossop.** 1983. The status and distribution of trumpeter swans (*Cygnus buccinator*) in the Yukon. Arctic 36: 76–81.

McKelvey, R., K. J. McCormick, and **L. J. Shandruk.** 1988. The status of Trumpeter Swans (*Cygnus buccinator*) in western Canada, 1985. Canadian Field-Naturalist 102: 495–499.

McKelvey, R. W., R. G. Davies, and **K. Morrisson.** 1991. The status of Trumpeter Swans wintering on Vancouver Island, British Columbia, Canada in 1989. Wildfowl 42: 84–87.

McNicol, D. K., and **M. Wayland.** 1992. Distribution of waterfowl broods in Sudbury area lakes in relation to fish, macroinvertebrates, and water chemistry. Canadian

Journal of Fisheries and Aquatic Sciences 49 (Supplement 1): 122–133.

McNicol, D. K., B. E. Bendell, and **D. G. McAulay.** 1987. Avian trophic relationships and wetland acidity. Transactions of the North American Wildlife and Natural Resources Conference 52: 619–627.

McNicol, D. K., B. E. Bendell, and **R. K. Ross.** 1987. Studies of the effects of acidification of aquatic wildlife in Canada: waterfowl and trophic relationships in small lakes in northern Ontario. Canadian Wildlife Service Occasional Paper number 62. 74 pages.

McNicol, D. K., B. E. Bendell, and **M. L. Mallory.** 1995. Evaluating macroinvertebrate responses to recovery from acidification in small lakes in Ontario, Canada. Water Air and Soil Pollution 85: 451–456.

Millar, J. B. 1971. Shoreline-area ratio as a factor in rate of water loss from small sloughs. Journal of Hydrology 14: 259–284.

Millar, J. B. 1973a. Estimation of area and circumference of small wetlands. Journal of Wildlife Management 37: 30–38.

Millar, J. B. 1973b. Vegetation changes in shallow marsh wetlands under improving moisture regime. Canadian Journal of Botany 51: 1443–1457.

Millar, J. B. 1976. Wetland classification in western Canada: a guide to marshes and shallow open water wetlands in the grasslands and parklands of the Prairie Provinces. Canadian Wildlife Service Report Series number 37. 37 pages.

Miller, D. R. 1976. Biology of the Kaminuriak Population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Canadian Wildlife Service Report Series number 36. 41 pages.

Miller, D. R., and **J. J. Robertson.** 1967. Results of tagging caribou at Little Duck Lake, Manitoba. Journal of Wildlife Management 31: 150–159.

Miller, F. L. 1972. Eruption and attrition of mandibular teeth in barren-ground caribou. Journal of Wildlife Management 36: 606–612.

Miller, F. L. 1974a. Age determination of caribou by annulations in dental cementum. Journal of Wildlife Management 38: 47–53.

Miller, F. L. 1974b. Distribution and numbers of white-tailed deer wintering in Gatineau Park, Quebec. Canadian Field-Naturalist 88: 41–45.

Miller, F. L. 1974c. Biology of the Kaminuriak Population of barren-ground caribou. Part 2: Dentition as an indicator of age and sex composition and socialization of the population. Canadian Wildlife Service Report Series number 31. 87 pages.

Miller, F. L. 1991. Estimating Bathurst Island Peary caribou and muskox populations. Arctic 44: 57–62.

Miller, F. L., and **E. Broughton.** 1973. Behaviour associated with mortality and stress in maternal-filial pairs of barren-ground caribou. Canadian Field-Naturalist 87: 21–25.

Miller, F. L., and **E. Broughton.** 1974. Calf mortality during 1970 on the calving ground of the Kaminuriak caribou. Canadian Wildlife Service Report Series number 26. 25 pages.

Miller, F. L., and **R. H. Russell.** 1974. Distribution and numbers of muskoxen (*Ovibos moschatus*) on western Queen Elizabeth Islands of arctic Canada. Journal of Mammalogy 55: 824–828.

Miller, F. L., and **A. Gunn.** 1978. Inter-island movements of Peary Caribou south of Viscount Melville Sound, Northwest Territories. Canadian Field-Naturalist 92: 327–333. [other publications on this subject in other areas]

Miller, F. L., A. Gunn. 1979. Responses of Peary caribou and muskoxen to turbo-helicopter harassment, Prince of Wales Island, Northwest Territories. Canadian Wildlife Service Occasional Paper number 40. 88 pages.

Miller, F. L., and **A. Gunn.** 1981. Play by Peary caribou calves before, during, and after helicopter harassment. Canadian Journal of Zoology 59: 823–827.

Miller, F. L., and **S. J. Barry.** 1992. Nonrandom distribution of antlers cast by Peary caribou bulls, Melville Island, Northwest Territories. Arctic 45: 252–257.

Miller, F.L., and **F. D. Reintjes.** 1995. Wolf-sightings in the Canadian Arctic islands. Arctic 48: 313–323.

Miller, F. L., C. J. Jonkel, and **G. D. Tessier.** 1972. Group cohesion and leadership response by barren-ground caribou to man-made barriers. Arctic 25: 193–202.

Miller, F. L., R. H. Russell, and **A. Gunn.** 1975. The recent decline of Peary caribou on western Queen Elizabeth Islands of Arctic Canada. Polarforschung 45: 17–21.

Miller, F. L., R. H. Russell, and **A. Gunn.** 1977. Distributions, movements and numbers of Peary caribou and muskoxen on western Queen Elizabeth Islands, Northwest Territories, 1972–74. Canadian Wildlife Service Report Series number 40. 54 pages.

Miller, F. L., E. J. Edmonds, and **A. Gunn.** 1982. Foraging behaviour of Peary caribou in response to springtime snow and ice conditions. Canadian Wildlife Service Occasional Paper number 48. 39 pages.

Miller, F. L., A. Gunn, and **E. Broughton.** 1985. Surplus killing as exemplified by wolf predation on newborn caribou. Canadian Journal of Zoology 63: 295–300.

Miller, F. L., E. Broughton, and **A. Gunn.** 1988. Mortality of migratory barren-ground caribou on the calving grounds of the Beverley herd, Northwest Territories, 1981–83. Canadian Wildlife Service Occasional Paper number 66. 24 pages.

Miller, F. L., A. Gunn, and **S. J. Barry.** 1988. Nursing by muskox calves before, during, and after helicopter overflights. Arctic 41: 231–235.

Mineau, P. 1982. Levels of major organochlorine contaminants in sequentially laid Herring Gull eggs. Chemosphere 11: 679–685.

Mineau, P. 1993. The hazard of Carbofuran to birds and other vertebrate wildlife. Canadian Wildlife Service Technical Report Series number 177. xxii + 96 pages.

Mineau, P., and **D. V. Weseloh.** 1981. Low disturbance monitoring of Herring Gull breeding success on the Great Lakes. Colonial Waterbirds 4: 138–142.

Mineau, P., and **D. B. Peakall.** 1987. An evaluation of avian impact assessment techniques following broad-scale forest insecticide sprays. Environmental Toxicology and Chemistry 6: 781–791.

Mineau, P., and **A. McLaughlin.** 1996. Conservation of biodiversity within Canadian agricultural landscapes: preserving habitat for wildlife. Journal of Agricultural and Environmental Ethics 9: 93–113.

Mineau, P., G. E. J. Smith, R. Markel, and **C.-S. Lam.** 1982. Aging Herring Gulls from hatching to fledging. Journal of Field Ornithology 53: 394–402.

Mineau, P., G. A. Fox, R. J. Norstrom, D. V. Weseloh, D. J. Hallett, and **J. A. Ellenton.** 1984. Using the Herring Gull to monitor levels and effects of organochlorine contaminants in the Canadian Great Lakes. Pages 425–452 *in* Toxic contaminants in the Great Lakes. *Edited by* J. R. Nriago and M. S. Simmons. J. Wiley and Sons, New York.

Mineau, P., P. J. Sheehan, and **A. Baril.** 1987. Pesticides and waterfowl on the Canadian prairies: A pressing need for research and monitoring. Pages 133–147 *in* The value of birds. *Edited by* A. W. Diamond and F. Filion. I.C.B.P. Technical Publication Number 6, Cambridge, U.K.

Mineau, P., K. M. S. Sundaram, S. Sundaram, C. Feng, D. G. Busby, and **P. A. Pearce.** 1990. An improved method to study the impact of pesticide sprays on small songbirds. Journal of Environmental Science and Health C25: 105–135.

Mineau, P., P. T. Boag, and **R. J. Beninger.** 1994. Effects of fenitrothion on memory for cache-site locations in Black-capped Chickadees. Environmental Toxicology and Chemistry 13: 281–290.

Mineau, P., D. C. Boersma, and **B. Collins.** 1994. An analysis of avian reproduction studies submitted for pesticide registration. Ecotoxicology and Environmental Safety 29: 304–329.

Mineau, P., B. T. Collins, and **A. Baril.** 1996. On the use of scaling factors to improve interspecies extrapolation of acute toxicity in birds. Regulatory Toxicology and Pharmacology 24: 24–29.

Moisan, G., R. I. Smith, and **R. K. Martinson.** 1967. The green-winged teal: its distribution, migration, and population dynamics. United States Fish and Wildlife Service Special Scientific Report – Wildlife number 100. 248 pages.

Montevecchi, W. A., and **A. J. Gaston.** *Editors.* 1991. Studies of high-latitude seabirds. 1. Behavioural, energetic, and oceanographic aspects of seabird feeding ecology. Canadian Wildlife Service Occasional Paper number 68. 54 pages.

Morgan, K. H., K. Vermeer, and **R. W. McKelvey.** 1991. Atlas of pelagic birds of western Canada. Canadian Wildlife Service Occasional Paper number 72. 69 pages.

Morrison, R. I. G. 1975. Migration and morphometrics of European Knot and Turnstone on Ellesmere Island, Canada. Bird-Banding 46: 290–301.

Morrison, R. I. G. 1983. A hemispheric perspective on the distribution and migration of some shorebirds in North and South America. Pages 84–94 *in* First western hemisphere waterfowl and waterbird symposium. *Edited by* H. Boyd. Canadian Wildlife Service and International Waterfowl Research Bureau.

Morrison, R. I. G. 1984. Migration systems of some New World shorebirds. Pages 125–202 *in* Shorebirds: migration and foraging behavior. *Edited by* J. Burger and B. L. Olla. Plenum Press, New York.

Morrison, R. I. G. 1991. Research requirements for shorebird conservation. Transactions of the North American Wildlife and Natural Resources Conference 56: 473–480.

Morrison, R. I. G., and **B. A. Harrington.** 1979. Critical shorebird resources in James Bay and eastern North America. Transactions of the North American Wildlife and Natural Resources Conference 44: 498–507.

Morrison, R. I. G., and **R. K. Ross.** 1989. Atlas of Nearctic shorebirds on the coast of South America. Canadian Wildlife Service Special Publication. 2 volumes. 325 pages.

Morrison, R. I. G., and **B. A. Harrington.** 1992. The migration system of the Red Knot *Calidris canutus rufa* in the New World. Wader Study Group Bulletin 64 (Supplement): 71–84.

Morrison, R. I. G., T. H. Manning, and **J. A. Hagar.** 1976. Breeding of the Marbled Godwit, *Limosa fedoa*, in James Bay. Canadian Field-Naturalist 90: 487–490.

Morrison, R. I. G., A. Bourget, R. Butler, H. L. Dickson, C. Gratto-Trevor, P. Hicklin, C. Hyslop, and **R. K. Ross.** 1994. A preliminary assessment of the status of shorebird populations in Canada. Canadian Wildlife Service Progress Notes number 208. 19 pages.

Morrison, R. I. G., C. Downes, and **B. Collins.** 1994. Population trends of shorebirds on fall migration in eastern Canada, 1974–1991. Wilson Bulletin 106: 431–447.

Morrison, R. I. G., N. C. Davidson, and **T. Piersma.** 1997. Daily energy expenditure and water turnover of shorebirds at Alert, Ellesmere Island, N.W.T. Canadian Wildlife Service Progress Notes number 211. 8 pages.

Mowat, F. M., and **A. H. Lawrie.** 1955. Bird observations from southern Keewatin and the interior of northern Manitoba. Canadian Field-Naturalist 69: 93–116.

Muir, D. C. G., R. J. Norstrom, and **M. Simon.** 1988. Organochlorine contaminants in Arctic marine food chains: Accumulation of specific polychlorinated biphenyls and chlordane-related compounds. Environmental Science and Technology 22: 1071–1079.

Mundy, K. R. D., and **D. R. Flook.** 1973. Background for managing grizzly bears in the national parks of Canada. Canadian Wildlife Service Report Series number 22. 34 pages.

Munro, D. A. 1950. A study of the economic status of sandhill cranes in Saskatchewan. Journal of Wildlife Management 14: 276–284.

Munro, D. A. 1960. Factors affecting reproduction of the Canada Goose (*Branta canadensis*). Proceedings International Ornithological Congress 12: 542–556.

Munro, D. A., and **J. B. Gollop.** 1955. Canada's place in flyway management. Transactions of the North American Wildlife Conference 20: 118–125.

Munro, D. A., and **R. D. Harris.** 1963. Du danger que constituent les oiseaux près des aérodromes du Canada. Pages 173–206 *in* Colloque le problème des oiseaux sur les aérodromes. Institut National de la Recherche Agronomique, Paris.

Munro, J. A. 1949a. Studies of waterfowl in British Columbia. Green-winged Teal. Canadian Journal of Research 27D: 149–178.

Munro, J. A. 1949b. Studies of waterfowl in British Columbia. Baldpate. Canadian Journal of Research 27D: 289–307.

Munro, J. A. 1949c. The birds and mammals of the Vanderhoof region, British Columbia. American Midland Naturalist 41: 1–138.

Munro, J. A. 1949d. Conservation of the trumpeter swan in Canada. Proceedings of Seventh Pacific Science Congress 4: 708–714.

Murphy, J. E. 1990. The 1985–1986 Canadian Peregrine Falcon, *Falco peregrinus*, survey. Canadian Field-Naturalist 104: 182–192.

Nettleship, D. N. 1972. Breeding success of the Common Puffin [*Fratercula arctica* (L.)] on different habitats at Great Island, Newfoundland. Ecological Monographs 42: 239–268.

Nettleship, D. N. 1974. Seabird colonies and distributions around Devon Island and vicinity. Arctic 27: 95–103.

Nettleship, D. N. 1976a. Gannets in North America: present numbers and recent changes. Wilson Bulletin 88: 300–313.

Nettleship, D. N. 1976b. Census techniques for seabirds of arctic and eastern Canada. Canadian Wildlife Service Occasional Paper number 25. 31 pages.

Nettleship, D. N. 1977. Seabird resources of eastern Canada: status, problems and prospects. Pages 96–108 *in*

Proceedings of Symposium "Canada's endangered species and habitats". *Edited by* T. Mosquin and C. Suchal. Canadian Nature Federation Special Publication number 6.

Nettleship, D. N. 1991. The diet of Atlantic Puffin chicks in Newfoundland before and after the initiation of an international capelin fishery, 1967–1984. Proceedings International Ornithological Congress 20: 2263–2271.

Nettleship, D. N., and **P. A. Smith. 1975.** Ecological sites in northern Canada. Canadian Commission International Biological Program, Ottawa. 330 pages.

Nettleship, D. N., and **A. J. Gaston.** 1979. Patterns of pelagic distribution of seabirds in western Lancaster Sound and Barrow Strait, Northwest Territories, in August and September 1976. Canadian Wildlife Service Occasional Paper number 39. 38 pages.

Nettleship, D. N., and **T. B. Birkhead.** *Editors*. 1985. The Atlantic Alcidae. The evolution, distribution and biology of the auks inhabiting the Atlantic Ocean and adjacent water areas. Academic Press, Harcourt Brace Jovanovitch, Publishers. 574 pages. [3 of 9 contributors were C.W.S. employees, including the senior editor]

Nettleship, D. N., and **D. B. Peakall.** 1987. Organochlorine residue levels in three high arctic species of colonially-breeding seabirds from Prince Leopold Island. Marine Pollution Bulletin 18: 434–438.

Nettleship, D. N., and **G. Chapdelaine.** 1988. Population size and status of the Northern Gannet *Sula bassanus* in North America, 1984. Journal of Field Ornithology 59: 120–127.

Nettleship, D. N., and **D. C. Duffy.** *Editors*. 1995. The Double–crested Cormorant: biology, conservation and management. Colonial Waterbirds volume 18, Special Publication 1. 256 pages.

Newell, K. L., and **F. G. Cooch.** 1980. A summary of waterfowl banding accomplishments in Canada, 1918–1978. Canadian Wildlife Service Progress Notes number 106. 38 pages.

Nieman, D. J., and **H. J. Dirschl.** 1973. Waterfowl populations on the Peace – Athabasca Delta, 1969 and 1970. Canadian Wildlife Service Occasional Paper number 17. 25 pages.

Nieman, D. J., G. S. Hochbaum, F. D. Caswell, and **B. C. Turner.** 1987. Monitoring hunter performance in prairie Canada. Transactions of the North American Wildlife and Natural Resources Conference 52: 233–245.

Noble, D. G., and **J. E. Elliott.** 1986. Environmental contaminants in Canadian seabirds, 1968–1985: trends and effects. Canadian Wildlife Service Technical Report Series number 13. 275 pages.

Noble, D. G., and **J. E. Elliott.** 1990. Levels of contaminants in Canadian raptors, 1966 to 1988; effects and temporal trends. Canadian Field-Naturalist 104: 222–243.

Noble, D. G., J. E. Elliott, and **J. L. Shutt.** 1993. Environmental contaminants in Canadian raptors, 1965–1989. Canadian Wildlife Service Technical Report Series number 91.

Norstrom, R. J., and **C. G. Muir.** 1994. Chlorinated hydrocarbon contaminants in arctic marine mammals. Science of the Total Environment 154: 107–128.

Norstrom, R. J., R. W. Risebrough, and **D. J. Cartwright.** 1976. Elimination of chlorinated dibenzofurans associated with polychlorinated biphenyls fed to Mallards (*Anas platyrhynchos*). Toxicology and Applied Pharmacology 37: 217–228.

Norstrom, R.J., D. J. Hallett, and **R. A. Sonstegard.** 1978. Coho salmon (*Oncorhynchus kisutch*) and Herring Gulls (*Larus argentatus*) as indicators of organochlorine contamination in Lake Ontario. Journal of the Fisheries Research Board of Canada 35: 1401–1409.

Norstom, R. J., D. J. Hallett, F. I. Onuska, and **M. E. Comba.** 1980. Mirex and its degradation products in Great Lakes Herring Gulls. Environmental Science and Technology 14: 860–866.

Norstrom, R. J., A. P. Gilman, and **D. J. Hallett.** 1981. Total organically-bound chlorine and bromine in Lake Ontario Herring Gull eggs, 1977, by instrumental neutron activation and chromatographic methods. Science of the Total Environment 20: 217–230.

Norstrom, R. J., T. P. Clark, D. A. Jeffery, H. T. Won, and **A. P. Gilman.** 1986. Dynamics of organochlorine compounds in herring gulls (*Larus argentatus*). I. Distribution and clearance of [^{14}C]DDE in free-living herring gulls (*Larus argentatus*). Environmental Toxicology and Chemistry 5: 41–48.

Norstrom, R. J., R. E. Schweinsberg, and **B. T. Collins.** 1986. Heavy metals and essential elements in livers of the Polar Bear (*Ursus maritimus*) in the Canadian Arctic. Science of the Total Environment 50: 195–212.

Norstrom, R. J., M. Simon, D. C. Muir, and **R. E. Schweinsburg.** 1988. Organochlorine contaminants in Arctic marine food chains: Identification, geographical distribution, and temporal trends in polar bears. Environmental Science and Technology 22: 1063–1071.

Norstrom, R. J., M. Simon, and **D. C. G. Muir.** 1990. Polychlorinated dibenzo-p-dioxins and dibenzofurans in marine mammals in the Canadian north. Environmental Pollution 66: 1–19.

Norstrom, R. J., D. C. G. Muir, C. A. Ford, M. Simon, C. R. Macdonald, and **P. Beland.** 1992. Indications of P450 monooxygenase activities in Beluga (*Delphinapterus leucas*) and narwhal (*Monodon monoceros*) from patterns of PCB, PCDD and PCDF accumulation. Marine Environmental Research 34: 267–272.

Novakowski, N. S. 1965. Cemental deposition as an age criterion in bison and the relation of incisor wear, eyelens weight, and dressed bison carcass weight to age. Canadian Journal of Zoology 43: 173–178.

Novakowski, N. S. 1966. Whooping Crane population dynamics on the nesting grounds, Wood Buffalo National Park, Northwest Territories, Canada. Canadian Wildlife Service Report Series number 1. 20 pages.

Novakowski, N. S. 1967. The winter bioenergetics of a beaver population in northern latitudes. Canadian Journal of Zoology 45: 1107–1118.

Novakowski, N. S. 1970. Endangered Canadian mammals. Canadian Field-Naturalist 84: 17–23.

Novakowski, N. S., J. G. Cousineau, J. B. Kolenosky, G. S. Wilton, and **L. P. Choquette.** 1963. Parasites and diseases of bison in Canada. II. Anthrax epizooty in the Northwest Territories. Transactions of the North American Wildlife and Natural Resources Conference 28: 233–239.

Outridge, P. M., and **A. M. Scheuhammer.** 1993. Bioaccumulation and toxicology of nickel: Implications for wild mammals and birds. Environmental Reviews 1: 172–197.

Outridge, P. M., and **A. M. Scheuhammer.** 1993. Bioaccumulation and toxicology of chromium: Implications for wildlife. Reviews of Environmental Contamination and Toxicology 130: 31–77.

Parker, G. R. 1971. Trends in populations of barren-ground caribou over the last two decades: a re-evaluation of the evidence. Canadian Wildlife Service Occasional Paper number 10. 9 pages.

Parker, G. R. 1972a. Biology of the Kaminuriak Population of barren-ground caribou. Part 1: Total numbers, mortality, recruitment, and seasonal distribution. Canadian Wildlife Service Report Series number 20. 93 pages.

Parker, G. R. 1972b. Distribution of barren-ground caribou harvest in northcentral Canada from ear-tag returns. Canadian Wildlife Service Occasional Paper number 15. 19 pages.

Parker, G. R. 1973. Distribution and densities of wolves within barren-ground caribou ranges in northern mainland Canada. Journal of Mammalogy 54: 341–348.

Parker, G. R. 1974. A population peak and crash of lemmings and Snowy Owls on Southampton Island, Northwest Territories. Canadian Field-Naturalist 88: 151–156.

Parker, G. R. 1975. An investigation of caribou range on Southampton Island, Northwest Territories. Canadian Wildlife Service Report Series number 33. 82 pages.

Parker, G. R. 1977. Morphology, reproduction, diet, and behavior of the arctic hare (*Lepus arcticus*) on Axel Heiberg Island, Northwest Territories. Canadian Field-Naturalist 91: 8–18.

Parker, G. R. 1978. The diets of muskoxen and Peary caribou on some islands of the Canadian High Arctic. Canadian Wildlife Service Occasional Paper number 35. 19 pages.

Parker, G. R. 1981. Physical and reproductive characteristics of an expanding woodland caribou population (*Rangifer tarandus caribou*) in northern Labrador. Canadian Journal of Zoology 59: 1929–1940.

Parker, G. R. 1984. Use of spruce plantations by Snowshoe Hare in New Brunswick. Forestry Chronicle 60: 162–166.

Parker, G. R. 1986. The seasonal diet of Coyotes, *Canis latrans*, in northern New Brunswick. Canadian Field-Naturalist 100: 74–77.

Parker, G. R. 1989. Effects of reforestation upon small mammal communities in New Brunswick. Canadian Field-Naturalist 103: 509–519.

Parker, G. R. 1991. Survival of juvenile American black ducks on a managed wetland in New Brunswick. Journal of Wildlife Management 55: 466–470.

Parker, G. R., and **R. K. Ross.** 1976. Summer habitat use by muskoxen (*Ovibos moschatus*) and Peary caribou (*Rangifer tarandus pearyi*) in the Canadian high arctic. Polarforschung 46: 12–25.

Parker, G. R., and **J. W. Maxwell.** 1980. Characteristics of a population of Muskrats (*Ondatra zibethicus zibethicus*) in New Brunswick. Canadian Field-Naturalist 94: 1–8.

Parker, G. R., and **G. E. J. Smith.** 1983. Sex- and age-specific reproductive and physical parameters of the bobcat (*Lynx rufus*) on Cape Breton Island, Nova Scotia. Canadian Journal of Zoology 61: 1771–1782.

Parker, G. R., and **J. W. Maxwell.** 1984. An evaluation of spring and fall trapping seasons for Muskrats, *Ondatra zibethicus*, in eastern Canada. Canadian Field-Naturalist 98: 293–304.

Parker, G. R., and **S. Luttich.** 1986. Characteristics of the wolf (*Canis lupus labradorius* Goldman) in northern Quebec and Labrador. Arctic 39: 145–149.

Parker, G. R., and **J. W. Maxwell.** 1989. Seasonal movements and winter ecology of the Coyote, *Canis latrans*, in northern New Brunswick. Canadian Field-Naturalist 103: 1–11.

Parker, G. R., D. C. Thomas, E. Broughton, and **D. R. Gray.** 1975. Crashes of muskox and Peary caribou populations in 1973–74 on the Parry Islands, Arctic Canada. Canadian Wildlife Service Progress Notes number 56. 10 pages.

Parker, G. R., J. W. Maxwell, L. D. Morton, and **G. E. J. Smith.** 1983. The ecology of the Lynx (*Lynx canadensis*) on Cape Breton Island. Canadian Journal of Zoology 61: 770–786.

Parker, G. R., M. J. Petrie, and **D. T. Sears.** 1992. Waterfowl distribution relative to wetland acidity. Journal of Wildlife Management 56: 268–274.

Parker, G. R., D. G. Kimball, and **B. Dalzell.** 1994. Bird communities in selected spruce and pine plantations in New Brunswick. Canadian Field-Naturalist 108: 1–9.

Patterson, J. H. 1979. Can ducks be managed by regulation? Experiences in Canada. Transactions of the North American Wildlife and Natural Resources Conference 44: 130–139.

Peakall, D. B. 1974. DDE: its presence in Peregrine eggs in 1948. Science (Washington) 183: 673–674.

Peakall, D. B. 1975. PCBs and their environmental effects. CRC Critical Reviews in Environmental Control 5: 469–509.

Peakall, D. B. 1976. The Peregrine Falcon (*Falco peregrinus*) and pesticides. Canadian Field-Naturalist 90: 301–307.

Peakall, D. B. 1985. Behavioral responses of birds to pesticides and other contaminants. Residue Reviews 96: 45–77.

Peakall, D. B. 1990. Prospects for the Peregrine Falcon, *Falco peregrinus*, in the nineties. Canadian Field-Naturalist 104: 168–173.

Peakall, D. B., and **A. P. Gilman.** 1979. Limitations of expressing organochlorine levels in eggs on a lipid weight basis. Bulletin of Environmental Contamination and Toxicology 23: 287–290.

Peakall, D. B., and **L. F. Kiff.** 1979. Eggshell thinning and DDE residue levels among Peregrine Falcons *Falco peregrinus*: a global perspective. Ibis 121: 200–204.

Peakall, D. B., and **J. R. Bart.** 1983. Impacts of aerial applications of insecticides on forest birds. CRC Critical Reviews in Environmental Control 13: 117–165.

Peakall, D. B., J. L. Lincer, R. W. Risebrough, L. B. Pritchard, and **W. B. Kinter.** 1973. DDE-induced eggshell thinning: structural and physiological effects in three species. Comparative and General Pharmacology 4: 303–311.

Peakall, D. B., T. J. Cade, C. M. White, and **J. R. Haugh.** 1975. Organochlorine residues in Alaska Peregrines. Pesticides Monitoring Journal 8: 255–260.

Peakall, D. B., G. A. Fox, A. P. Gilman, D. J. Hallett, and **R. J. Norstrom.** 1980. Reproductive success of Herring Gulls as an indicator of Great Lakes water quality. Pages 337–344 *in* Hydrocarbons and halogenated hydrocarbons in the aquatic environment. *Edited by* B. K. Afghan and D. MacKay. Plenum Press, New York.

Peakall, D. B., D. J. Hallett, J. R. Bend, G. L. Foureman, and **D. S. Miller.** 1982. Toxicity of Prudhoe Bay crude oil and its aromatic fractions to nestling Herring Gulls. Environmental Research 27: 206–215.

Peakall, D. B., D. S. Miller, and **W. B. Kinter.** 1983. Toxicity of crude oils and their fractions to nestling gulls. 1. Physiological and biochemical effects. Marine Environmental Research 8: 63–71.

Peakall, D. B., R. J. Norstrom, A. D. Rahimtula, R. D. Butler, and **F. A. Leighton.** 1986. Characterization of mixed function oxidase systems of the nestling Herring Gull and its implications for bioeffects monitoring. Environmental Toxicology and Chemistry 5: 379–385.

Peakall, D. B., P. G. Wells, and **D. MacKay.** 1987. A hazard assessment of chemically dispersed oil spills and seabirds. Marine Environmental Research 22: 91–106.

Peakall, D. B., D. G. Noble, J. E. Elliott, J. D. Somers, and **G. Erickson.** 1990. Environmental contaminants in Canadian Peregrine Falcons, *Falco peregrinus*: a biological assessment. Canadian Field-Naturalist 104: 244–254.

Pearce, P. A. 1971. Side effects of forest spraying in New Brunswick. Transactions of the North American Wildlife and Natural Resources Conference 36: 163–170.

Pearce, P. A., and **N. R. Garrity.** 1981. Impact of aminocarb (Matacil) spraying on forest songbirds in northern New Brunswick. Canadian Wildlife Service Progress Notes number 121. 17 pages.

Pearce, P. A., D. R. Peakall, and **A. J. Erskine.** 1976. Impact on forest birds of the 1975 spruce budworm spray operation in New Brunswick. Canadian Wildlife Service Progress Notes number 62. 7 pages.

Pearce, P. A., I. M. Price, and **L. M. Reynolds.** 1976. Mercury in waterfowl from eastern Canada. Journal of Wildlife Management 40: 694–703.

Pearce, P. A., L. M. Reynolds, and **D. B. Peakall.** 1978. DDT residues in rainwater in New Brunswick and estimate of aerial transport of DDT into the Gulf of St. Lawrence, 1967–68. Pesticides Monitoring Journal 11: 199–204.

Pearce, P. A., G. L. Brun, and **J. Witteman.** 1979. Off–target fallout of fenitrothion during 1978 forest spraying operations in New Brunswick. Bulletin of Environmental Contamination and Toxicology 23: 503–508.

Pearce, P. A., D. R. Peakall, and **A. J. Erskine.** 1979. Impact on forest birds of the 1976 spruce budworm spray operation in New Brunswick. Canadian Wildlife Service Progress Notes number 97. 15 pages.

Pearce, P. A., D. B. Peakall, and **L. M. Reynolds.** 1979. Shell-thinning and residues of organochlorines and mercury in seabird eggs, eastern Canada, 1970–1976. Pesticides Monitoring Journal 13: 61–68.

Pearce, P. A., J. E. Elliott, D. B. Peakall, and **R. J. Norstrom.** 1989. Organochlorine contaminants in eggs of seabirds in the northwest Atlantic, 1968–1984. Environmental Pollution 56: 217–235.

Pearson, A. M. 1975. The northern interior grizzly bear *Ursus arctos* L. Canadian Wildlife Service Report Series number 34. 84 pages.

Pearson, A. M., and **D. W. Halloran.** 1972. Hematology of the brown bear (*Ursus arctos*) from southwestern Yukon Territory, Canada. Canadian Journal of Zoology 50: 279–286.

Peden, D. G. 1976. Botanical composition of bison diets on shortgrass plains. American Midland Naturalist 96: 225–229.

Peden, D. G. 1982. Factors associated with growth of wild rice in northern Saskatchewan. Arctic 35: 307–311.

Peden, D. G., and **E. Whiting.** 1976. Variation in plasma proteins among Mallards collected from three different geographic regions. Canadian Wildlife Service Progress Notes number 65. 6 pages.

Peden, D. G., and **G. J. Kraay.** 1979. Comparison of blood characteristics in plains bison, wood bison, and their hybrids. Canadian Journal of Zoology 57: 1778–1784.

Peer, D. L., L. E. Linkletter, and **P. W. Hicklin.** 1986. Life history and reproductive biology of *Corophium volutator* (Crustacea: Amphipoda) and the influence of shorebird predation on population structure in Chignecto Bay, Bay of Fundy, Canada. Netherlands Journal of Sea Research 20: 359–373.

Pettit, K. E., C. A. Bishop, D. V. Weseloh, and **R. J. Norstrom.** 1994a,b. An atlas of contaminants in the eggs of fish-eating colonial birds of the Great Lakes (1989–1992). Volumes 1 and 2. Canadian Wildlife Service Technical Reports numbers 193 and 194.

Pettit, K. E., C. A. Bishop, and **R. J. Brooks.** 1995. Home range and movements of the Common Snapping Turtle, *Chelydra serpentina serpentina*, in a coastal wetland of Hamilton Harbour, Lake Ontario, Canada. Canadian Field-Naturalist 109: 192–200.

Phaneuf, D., J.-L. DesGranges, and **J. Rodrigue.** 1995. Contamination of local wildlife following a fire at a PCB warehouse in St-Basile le Grand, Québec. Archives of Environmental Contamination and Toxicology 28: 145–153.

Piatt, J. F., and **D. N. Nettleship.** 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Marine Pollution Bulletin 18(6B): 344–349.

Pimlott, D. H. 1952. The economic status of the Herring Gulls of the Grand Manan Archipelago. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 5. 76 pages.

Polischuk, S. C., R. J. Letcher, R. J. Norstrom, and **M. A. Ramsay.** 1995. Preliminary results on the kinetics of organochlorines in western Hudson Bay polar bear (*Ursus maritimus*). Science of the Total Environment 160,161: 465–472.

Poston, H. J. 1974. Home range and breeding biology of the Shoveler. Canadian Wildlife Service Report Series number 25. 48 pages.

Poston, B. [= H. J.], D. M. Ealey, P. S. Taylor, and **G. B. McKeating.** 1990. Priority migratory bird habitats of Canada's Prairie Provinces. Canadian Wildlife Service, Western and Northern Region. 107 pages + map.

Poulin, R. M., K. L. Newell, S. J. O'Donnell, and **S. Wendt.** 1979. Annual report to banders: Summary of birds banded in Canada in 1977. Canadian Wildlife Service Progress Notes number 102. 18 pages.

Prach, R. W., and **A. R. Smith.** 1992. Breeding distribution and numbers of black guillemots in Jones Sound, N.W.T. Arctic 45: 111–114.

Price, I. M. 1977. Environmental contaminants in relation to Canadian wildlife. Transactions of the North American Wildlife and Natural Resources Conference 42: 382–396.

Price, I. M., and **D. V. Weseloh.** 1986. Increased numbers and productivity of Double-crested Cormorants, *Phalacrocorax auritus*, on Lake Ontario. Canadian Field-Naturalist 100: 474–482.

Proulx, G., D. V. C. Weseloh, J. E. Elliott, S. Teeple, P. A. M. Anghern, and **P. Mineau.** 1987. Organochlorine and PCB residues in Lake Erie Mink populations. Bulletin of Environmental Contamination and Toxicology 39: 939–944.

Radvanyi, A. 1966. Destruction of radio-tagged seeds of white spruce by small mammals during summer months. Forest Science 12: 307–315.

Radvanyi, A. 1970. Small mammals and regeneration of white spruce forests in western Alberta. Ecology 51: 1102–1105.

Radvanyi, A. 1971. Lodgepole Pine seed depredation by small mammals in western Alberta. Forest Science 17: 213–217.

Radvanyi, A. 1975. Harmful effects of small mammal populations on a tree plantation in southern Ontario. Canadian Field-Naturalist 89: 53–57.

Reed, A. 1976. Geese, nutrition, and farmland. Wildfowl 27: 153–156.

Reed, A., *Editor.* 1986. Eider ducks in Canada. Canadian Wildlife Service Report Series number 47. 175 pages.

Reed, A. 1991. Subsistence harvesting of waterfowl in northern Quebec: Goose hunting and the James Bay Cree. Transactions of the North American Wildlife and Natural Resources Conference 56: 344–349.

Reed, A. 1993. Duration of family bonds of Brent Geese *Branta bernicla* on the Pacific coast of North America. Wildfowl 44: 33–38.

Reed, A., and **A. Bourget.** 1977. Distribution and abundance of waterfowl wintering in southern Quebec. Canadian Field-Naturalist 91: 1–7.

Reed, A., and **P. Chagnon.** 1987. Greater snow geese on Bylot Island, Northwest Territories, 1983. Journal of Wildlife Management 51: 128–131.

Reed, A., and **N. Plante.** 1997. Decline in body mass, size, and condition of Greater Snow Geese, 1975–94. Journal of Wildlife Management 61: 413–419.

Reed, A., G. Chapdelaine, and **P. Dupuis.** 1977. Use of farmland in spring by migrating Canada Geese in the St. Lawrence valley, Quebec. Journal of Applied Ecology 14: 667–680.

Reed, A., P. Dupuis, K. Fischer, and **J. Moser.** 1980. An aerial survey of breeding geese and other wildlife in Foxe Basin and northern Baffin Island, Northwest Territories, July 1979. Canadian Wildlife Service Progress Notes number 114. 21 pages.

Reed, A., H. Boyd, and **J. S. Wendt.** 1981. Characteristics of the harvest of Greater Snow Geese. Transactions Northeastern Section Wildlife Society 38: 77–86.

Reed, A., P. Dupuis, and **G. E. J. Smith.** 1987. A survey of Lesser Snow Geese on Southampton and Baffin Islands, NWT, 1979. Canadian Wildlife Service Occasional Paper number 61. 22 pages.

Reed, A., M. Davison, and **D. K. Kraege.** 1989. Segregation of brent geese wintering and staging in Puget Sound and the Strait of Georgia. Wildfowl 40: 22–31.

Reed, A., R. Stehn, and **D. Ward.** 1989. Autumn use of Izembek Lagoon, Alaska, by brant from different breeding areas. Journal of Wildlife Management 53: 720–725.

Reed, A., H. Boyd, P. Chagnon, and **J. Hawkings.** 1992. The numbers and distribution of greater snow geese on Bylot Island and near Jungersen Bay, Baffin Island, in 1988 and 1983. Arctic 45: 115–119.

Reed, A., R. Benoit, R. Lalumière, and **M. Julien.** 1996. Duck use of the coastal habitats of northeastern James Bay. Canadian Wildlife Service Occasional Paper number 90. 45 pages.

Reed, A., R. Benoit, M. Julien, and **R. Lalumière.** 1996. Goose use of the coastal habitats of northeastern James Bay. Canadian Wildlife Service Occasional Paper number 92. 33 pages.

Reynolds, H. W., and **A. W. J. Hawley.** *Editors.* 1987. Bison ecology in relation to agricultural development in the Slave River lowlands, NWT. Canadian Wildlife Service Occasional Paper number 63. 72 pages.

Reynolds, H. W., R. M. Hansen, and **D. G. Peden.** 1978. Diets of the Slave River Lowland bison herd, Northwest Territories, Canada. Journal of Wildlife Management 42: 581–590.

Robert, M., and **P. Laporte.** 1991. History and current status of the Loggerhead Shrike in Quebec. Canadian Wildlife Service Progress Notes number 196. 6 pages.

Robert, M., and **P. Laporte.** 1997. Field techniques for studying breeding Yellow Rails. Journal of Field Ornithology 68: 56–63.

Rodway, M. S., H. M. Regehr, and **J.–P. L. Savard.** 1993. Activity levels of Marbled Murrelets in different inland habitats in the Queen Charlotte Islands, British Columbia. Canadian Journal of Zoology 71: 977–984.

Ross, R. K. 1982. Duck distribution along the James and Hudson Bay coasts of Ontario. Le Naturaliste canadien 109: 927–932.

Ross, R. K. 1983. An estimate of the Black Scoter, *Melanitta nigra*, population moulting in James and Hudson Bays. Canadian Field-Naturalist 97: 147–150.

Ross, R. K. 1985. Helicopter vs. ground surveys of waterfowl in the boreal forest. Wildlife Society Bulletin 13: 153–157.

Russell, R. H. 1975. The food habits of polar bears of James Bay and southwest Hudson Bay in summer and autumn. Arctic 28: 117–129.

Ryder, J. P. 1967. The breeding biology of Ross' Goose in the Perry River region, Northwest Territories. Canadian Wildlife Service Report Series number 3. 56 pages.

Sanderson, J. T., J. E. Elliott, R. J. Norstrom, P. E. Whitehead, L. E. Hart, K. M. Cheng, and **G. D. Bellward.** 1994. Monitoring biological effects of polychlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls in Great Blue Heron chicks (*Ardea herodias*) in British Columbia. Toxicology and Environmental Health 41: 435–450.

Sanderson, J. T., R. J. Norstrom, J. E. Elliott, P. E. Hart, K. M. Cheng, and **G. D. Bellward.** 1994. Biological effects of polychlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls in Double-crested Cormorant chicks (*Phalocrocorax auritus*). Toxicology and Environmental Health 41: 247–265.

Savard, J.-P. L. 1982. Intra- and inter-specific competition between Barrow's goldeneye (*Bucephala islandica*) and bufflehead (*Bucephala albeola*). Canadian Journal of Zoology 60: 3439–3446.

Savard, J.-P. L. 1984. Territorial behaviour of Common Goldeneye, Barrow's Goldeneye and Bufflehead in areas of sympatry. Ornis Scandinavica 15: 211–216.

Savard, J.-P. 1987. Causes and functions of brood amalgamation in Barrow's Goldeneye and Bufflehead. Canadian Journal of Zoology 65: 1548–1553.

Savard, J.-P. 1988a. Use of nest boxes by Barrow's Goldeneyes: nesting success and effect on the breeding population. Wildlife Society Bulletin 16: 125–132.

Savard, J. P. L. 1988b. Winter, spring, and summer territoriality in Barrow's Goldeneye: characteristics and benefits. Ornis Scandinavica 19: 119–128.

Savard, J.-P. L., and **J. N. M. Smith.** 1987. Interspecific aggression by Barrow's Goldeneye: a description and functional analysis. Behaviour 102: 168–184.

Savard, J.-P. L., and **J. McA. Eadie.** 1989. Survival and breeding philopatry in Barrow's and Common Goldeneye. Condor 91: 198–203.

Savard, J.-P. L., and **P. Lamothe.** 1991. Distribution, abundance, and aspects of the breeding ecology of Black Scoters, *Melanitta nigra*, and Surf Scoters, *M. perspicillata*, in northern Quebec. Canadian Field-Naturalist 105: 488–496.

Savard, J.-P. L., G. E. J. Smith, and **J. N. M. Smith.** 1991. Duckling mortality in Barrow's Goldeneye and Bufflehead broods. Auk 108: 568–577.

Scheuhammer, A. M. 1987a. The chronic toxicity of aluminium, cadmium, mercury and lead in birds: a review. Environmental Pollution 46: 263–295.

Scheuhammer, A. M. 1987b. Reproductive effects of chronic, low-level dietary metal exposure in birds. Transactions of the North American Wildlife and Natural Resources Conference 52: 658–664.

Scheuhammer, A. M. 1989. Monitoring wild bird populations for lead exposure. Journal of Wildlife Management 53: 759–765.

Scheuhammer, A. M. 1991. Effects of acidification on the availability of toxic metals and calcium to wild birds and mammals. Environmental Pollution 71: 329–375.

Scheuhammer, A. M., and **L. K. Wilson.** 1990. Effects of lead and pesticides on ALA-d of Ring Doves (*S. risoria*). Environmental Toxicology and Chemistry 9: 1379–1386.

Scheuhammer, A. M., and **P. B. Blancher.** 1994. Potential risk to Common Loons (*Gavia immer*) from methylmercury exposure in acidified lakes. Hydrobiologia 279/280: 445–455.

Scheuhammer, A. M., and **S. L. Norris.** 1995. A review of the environmental impacts of lead shotshell ammunition and lead fishing weights in Canada. Canadian Wildlife Service Occasional Paper number 88. 52 pages.

Scheuhammer, A. M., and **K. M. Dickson.** 1996. Patterns of environmental lead exposure in waterfowl in eastern Canada. Ambio 25: 14–20.

Scheuhammer, A. M., and **D. M. Templeton.** 1997. The use of stable isotope ratios to distinguish sources of lead exposure in wild birds. Ecotoxicology 7: 37–42.

Scheuhammer, A. M., D. K. McNicol, M. L. Mallory, and **J. J. Kerekes.** 1996. Relationship between lake chemistry, and calcium and trace metal concentrations of aquatic invertebrates eaten by breeding insectivorous waterfowl. Environmental Pollution 96: 235–247.

Scheuhammer, A. M., C. M. Atchison, A. H. K. Wong, and **D. C. Evers.** 1997. Mercury exposure in breeding Common Loons (*Gavia immer*) in central Ontario, Canada. Journal of Environmental Toxicology and Chemistry 17: 191–196.

Scheuhammer, A. M., A. H. K. Wong, and **D. Bond.** 1997. Mercury and selenium accumulation in Common Loons (*Gavia immer*) and Common Mergansers (*Mergus merganser*) from eastern Canada. Journal of Environmental Toxicology and Chemistry 17: 197–201.

Schmutz, J. K., R. W. Fyfe, U. Banasch, and **H. Armbruster.** 1991. Routes and timing of migration of falcons banded in Canada. Wilson Bulletin 103: 44–58.

Schultz, F. H. 1955. Investigation of the spawning of Northern Pike in Prince Albert National Park, Saskatchewan, 1953. Canadian Wildlife Service Wildlife Management Bulletin series 3, number 4. 21 pages.

Scotter, G. W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Canadian Wildlife Service Wildlife Management Bulletin, series 1, number 18. 109 pages.

Scotter, G. W. 1965. Chemical composition of forage lichens from northern Saskatchewan as related to use by barren-ground caribou. Canadian Journal of Plant Science 45: 246–250.

Scotter, G. W. 1966. A contribution to the flora of the eastern arm of Great Slave Lake, Northwest Territories. Canadian Field-Naturalist 80: 1–18.

Scotter, G. W. 1967a. The winter diet of barren–ground caribou in northern Canada. Canadian Field-Naturalist 81: 33–39.

Scotter, G. W. 1967b. Effects of fire on barren–ground caribou and their forest habitat in northern Canada. Transactions of the North American Wildlife and Natural Resources Conference 32: 246–254.

Scotter, G. W. 1972. Chemical composition of forage plants from the Reindeer Preserve, Northwest Territories. Arctic 25: 21–27.

Scotter, G. W. 1991. The Beverly and Kaminuriak Caribou Management Board: An example of cooperative management. Transactions of the North American Wildlife and Natural Resources Conference 56: 309–320.

Scotter, G. W., and **J. W. Thomson.** 1961. Lichens of northern Saskatchewan. Bryologist 64: 240–247.

Scotter, G. W., and **S. C. Zoltai.** 1982. Earth hummocks in the Sunshine area of the Rocky Mountains, Alberta and British Columbia. Arctic 35: 411–416.

Scotter, G. W., L. N. Carbyn, W. P. Neily, and **J. D. Henry.** 1985. Birds of Nahanni National Park, Northwest Territories. Saskatchewan Natural History Society Special Publication number 15. 74 pages.

Sen, A. R. 1970a. On the bias in estimation due to imperfect frame in the Canadian waterfowl surveys. Journal of Wildlife Management 34: 703–706.

Sen, A. R. 1970b. Relative efficiency of sampling systems in the Canadian Waterfowl Harvest Survey. Biometrics 26: 315–326.

Sen, A. R. 1971. Increased precision in Canadian waterfowl harvest survey through successive sampling. Journal of Wildlife Management 35: 664–668.

Sen, A. R. 1973. Response errors in Canadian waterfowl surveys. Journal of Wildlife Management 37: 485–491.

Sen, A. R. 1982. A review of some important techniques in sampling wildlife. Canadian Wildlife Service Occasional Paper number 49. 15 pages.

Sen, A. R., J. Tourigny, and **G. E. J. Smith.** 1974. On the line transect sampling method. Biometrics 30: 329–340.

Shaffer, F., and **P. Laporte.** 1994. Diet of Piping Plovers on the Magdalen Islands, Quebec. Wilson Bulletin 106: 531–536.

Sheehan, P. K., A. Baril, P. Mineau, D. K. Smith, A. Harfenist, and **W. K. Marshall.** 1987. The impact of pesticides on the ecology of prairie-nesting ducks. Canadian Wildlife Service Technical Report Series number 19. 653 pages.

Simpson, K., J. N. M. Smith, and **J. P. Kelsall.** 1987. Correlates and consequences of coloniality in Great Blue Herons. Canadian Journal of Zoology 65: 572–577.

Sinclair, P. H., and **J. E. Elliott.** 1994. Birds and pesticides in orchards of the south Okanagan/Similkameen region of British Columbia. Canadian Wildlife Service Technical Report Series number 185. 54 pages.

Sirois, J., M. A. Fournier, and **M. F. Kay.** 1995. The colonial waterbirds of Great Slave Lake, Northwest Territories: an annotated atlas. Canadian Wildlife Service Occasional Paper number 89. 57 pages.

Smith, A. G., and **H. R. Webster.** 1955. Effects of hail storms on waterfowl populations in Alberta, Canada – 1953. Journal of Wildlife Management 19: 368–374.

Smith, A. R. 1996. Atlas of Saskatchewan birds. Saskatchewan Natural History Society Special Publication number 22 (number 4 in Manley Callin Series). 456 pages.

Smith, P. A. 1978. Résumé of the trade in polar bear hides in Canada, 1976–77. Canadian Wildlife Service Progress

Notes number 89. 5 pages. [Last in a series of 5 annual reports.]

Smith, P., I. Stirling, C. Jonkel, and **I. Juniper.** 1975. Notes on the present status of the polar bear (*Ursus maritimus*) in Ungava Bay and northern Labrador. Canadian Wildlife Service Progress Notes number 53. 8 pages.

Solman, V. E. F. 1951. Limnological investigations in Cape Breton Highlands National Park, Nova Scotia, 1947. Canadian Wildlife Service Wildlife Management Bulletin series 3, number 3. 49 pages.

Solman, V. E. F. 1966. The ecological control of bird hazards to aircraft. Proceedings Bird Control Seminar, Bowling Green University, Bowling Green, Ohio 3: 38–52.

Solman, V. E. F. 1973. Canada's inventory of land-wildlife capabilities. Transactions of the North American Wildlife and Natural Resources Conference 38: 354–359.

Solman, V. E. F. 1981. Federal wildlife conservation work in Canada in the past 100 years. Canadian Field-Naturalist 95: 31–34.

Solman, V. E. F., J. P. Cu[e]rrier, and **W. C. Cable.** 1952. Why have fish hatcheries in Canada's National Parks? Transactions of the North American Wildlife Conference 17: 226–234.

Soper, J. D. 1951. Waterfowl and related investigations in the Peace-Athabaska delta region of Alberta, 1949. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 2. 63 pages + photos.

Soper, J. D. 1952. The birds of Elk Island National Park, Alberta, Canada. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 3. 60 pages. [Several other CWS bulletins, mostly by the same author, covered bird and mammal inventories conducted in other western National Parks during 1940–46.]

Soper, J. D. 1954. Waterfowl and other ornithological investigations in Yukon Territory, Canada, 1950. Canadian Wildlife Service Wildlife Management Bulletin series 2, number 7. 55 pages + photos.

Soper, J. D. 1961. The mammals of Manitoba. Canadian Field-Naturalist 75: 171–219.

Soper, J. D. 1970. The mammals of Jasper National Park. Canadian Wildlife Service Report Series number 10. 80 pages.

Soper, J. D. 1973. The mammals of Waterton Lakes National Park. Canadian Wildlife Service Report Series number 23. 55 pages.

Sorensen, M. F. 1968. An appraisal of the no-Mallard restriction during a portion of the 1967 waterfowl hunting season in southern Manitoba. Canadian Wildlife Service Progress Notes number 6. 13 pages.

Sorensen, M. F. 1978. Observations of Mallards in the parkland of Alberta. Canadian Wildlife Service Occasional Paper number 36. 20 pages.

Stalling, D., R. J. Norstrom, L. Smith, and **M. Simon.** 1985. Patterns of PCDD, PCDF and PCB contamination in Great Lakes fish and birds and their characterization by principal components analysis. Chemosphere 14: 627–643.

Stelfox, J. S. 1971. Bighorn sheep in the Canadian Rockies: A history 1800–1970. Canadian Field-Naturalist 85: 101–122.

Stelfox, J. G. 1977. Range ecology of Rocky Mountain bighorn sheep in Canadian national parks. Canadian Wildlife Service Report Series number 39. 49 pages.

Stelfox, J. S., E. S. Telfer, and **J. R. McGillis.** 1976. Effects of clearcut logging on wild ungulates in the central Alberta foothills. Forestry Chronicle 52: 65–70.

Stephen, W. J. D. 1961. Experimental use of acetylene exploders to control duck damage. Transactions of the North American Wildlife and Natural Resources Conference 26: 98–111.

Stephen, W. J. D. 1967. Bionomics of the Sandhill Crane. Canadian Wildlife Service Report Series number 2. 48 pages.

Stephen, W. J. D. 1979. Toward population goals for Canvasback. Canadian Wildlife Service Progress Notes number 96. 9 pages.

Stephen, W. J. D., and **R. S. Miller.** 1966. Dispersion within flocks of sandhill cranes. Ecology 47: 281–285.

Stephen, W. J. D., R. S. Miller, and **J. P. Hatfield.** 1966. Demographic factors affecting management of sandhill cranes. Journal of Wildlife Management 30: 581–589.

Sterling, T., and **A. Dzubin.** 1967. Canada goose molt migrations to the Northwest Territories. Transactions of the North American Wildlife and Natural Resources Conference 32: 355–373.

Stevens, W. E. 1953. The northwestern muskrat of the Mackenzie delta, Northwest Territories, 1947–48. Canadian Wildlife Service Wildlife Management Bulletin series 1, number 8. 40 pages.

Stirling, I. 1974. Midsummer observations on the behaviour of wild polar bears (*Ursus maritimus*). Canadian Journal of Zoology 52: 1191–1198.

Stirling, I. 1980. The biological importance of polynyas in the Canadian Arctic. Arctic 33: 303–315.

Stirling, I. 1988. Polar bears. University of Michigan Press, Ann Arbor. 220 pages.

Stirling, I. 1991. Management of shared populations of polar bears. Transactions of the North American Wildlife and Natural Resources Conference 56: 488–493.

Stirling, I., and **E. H. McEwen.** 1975. The caloric value of whole ringed seals (*Phoca hispida*) in relation to polar bear (*Ursus maritimus*) ecology and hunting behavior. Canadian Journal of Zoology 53: 1021–1027.

Stirling, I., and **W. R. Archibald.** 1977. Aspects of predation of seals by polar bears. Journal of the Fisheries Research Board of Canada 34: 1126–1129.

Stirling, I., and **P. B. Latour.** 1978. Comparative hunting abilities of polar bear cubs of different ages. Canadian Journal of Zoology 56: 1768–1772.

Stirling, I., and **D. B. Siniff.** 1979. Underwater vocalizations of leopard seals (*Hydrurga leponyx*) and crabeater seals (*Lobodon carcinophagus*) near the South Shetland Islands, Antarctica. Canadian Journal of Zoology 57: 1244–1248.

Stirling, I., and **H. P. L. Kiliaan.** 1980. Population ecology studies of the polar bear in northern Labrador. Canadian Wildlife Service Occasional Paper number 42. 19 pages.

Stirling, I., and **H. Cleator.** *Editors.* 1981. Polynyas in the Canadian Arctic. Canadian Wildlife Service Occasional Paper number 45. 70 pages.

Stirling, I., and **D. Andriashek.** 1992. Terrestrial maternity denning of polar bears in the eastern Beaufort Sea area. Arctic 45: 363–366.

Stirling, I., and **A. E. Derocher.** 1993. Possible impacts of climatic warming on polar bears. Arctic 46: 240–245.

Stirling, I., A. M. Pearson, and **F. L. Bunnell.** 1976. Population ecology studies of polar and grizzly bears in northern Canada. Transactions of the North American Wildlife and Natural Resources Conference 41: 421–430.

Stirling, I., W. R. Archibald, and **D. DeMaster.** 1977. Distribution and abundance of seals in the eastern Beaufort Sea. Journal of the Fisheries Research Board of Canada 34: 976–988.

Stirling, I., C. Jonkel, P. Smith, R. Robertson, and **D. Cross.** 1977. The ecology of the polar bear (*Ursus maritimus*) along the western coast of Hudson Bay. Canadian Wildlife Service Occasional Paper number 33. 62 pages.

Stirling, I., W. Calvert, and **D. Andriashek.** 1980. Population ecology studies of the polar bear in the area of southeastern Baffin Island. Canadian Wildlife Service Occasional Paper number 44. 31 pages.

Stirling, I., M. Kingsley, and **W. Calvert.** 1982. The distribution and abundance of seals in the western Beaufort Sea, 1974–79. Canadian Wildlife Service Occasional Paper number 47. 23 pages.

Stirling, I., W. Calvert, and **H. Cleator.** 1983. Underwater vocalizations as a tool for studying the distribution and relative abundance of wintering pinnipeds in the High Arctic. Arctic 36: 262–274.

Stirling, I., W. Calvert, and **C. Spencer.** 1987. Evidence of stereotyped underwater vocalizations of male Atlantic walruses (*Odobenus rosmarus rosmarus*). Canadian Journal of Zoology 65: 2311–2321.

Stirling, I., D. Andriashak, and **W. Calvert.** 1993. Habitat preferences of polar bears in the western Canadian Arctic in late winter and spring. Polar Record 29: 13–24.

Stirrett, G. M. 1954. Field observations of geese in James Bay, with special reference to the blue goose. Transactions of the North American Wildlife Conference 19: 211–220.

Struger, J., J. E. Elliott, C. A. Bishop, M. E. Obbard, R. J. Norstrom, D. V. Weseloh, and **M. Simon.** 1993. Environmental contaminants in snapping turtle eggs from the Great Lakes – St. Lawrence River basin of Ontario, Canada (1981, 1984). Journal of Great Lakes Research 19: 681–694.

Sugden, L. G. 1971. Metabolizable energy of small grains for mallards. Journal of Wildlife Management 35: 781–785.

Sugden, L. G. 1973. Feeding ecology of Pintail, Gadwall, American Wigeon and Lesser Scaup ducklings in southern Alberta. Canadian Wildlife Service Report Series number 24. 43 pages.

Sugden, L. G. 1976a. Waterfowl damage to Canadian grain: current problems and research needs. Canadian Wildlife Service Occasional Paper number 24. 24 pages.

Sugden, L. G. 1976b. Experimental release of canvasbacks on breeding habitat. Journal of Wildlife Management 40: 716–720.

Sugden, L. G. 1977. Horned Grebe breeding habitat in Saskatchewan parklands. Canadian Field-Naturalist 91: 372–376.

Sugden, L. G. 1978. Canvasback habitat use and production in Saskatchewan parklands. Canadian Wildlife Service Occasional Paper number 34. 30 pages.

Sugden, L. G. 1979a. Mallard use of small wetlands during the crop damage season. Canadian Wildlife Service Progress Notes number 100. 5 pages.

Sugden, L. G. 1979b. Grain consumption by mallards. Wildlife Society Bulletin 7: 35–39.

Sugden, L. G. 1979c. Habitat use by nesting American Coots in Saskatchewan parklands. Wilson Bulletin 91: 599–607.

Sugden, L. G. 1980. Parasitism of Canvasback nests by Redheads. Journal of Field Ornithology 51: 361–364.

Sugden, L. G., and **D. A. Benson.** 1970. An evaluation of loafing rafts for attracting ducks. Journal of Wildlife Management 34: 340–343.

Sugden, L. G., and **L. E. Harris.** 1972. Energy requirements and growth of captive lesser scaup. Poultry Science 51: 625–633.

Sugden, L. G., and **D. W. Goerzen.** 1979. Preliminary measurements of grain wasted by field-feeding mallards. Canadian Wildlife Service Progress Notes number 104. 5 pages.

Sugden, L. G., and **E. A. Driver.** 1980. Natural foods of mallards in Saskatchewan parklands during late summer and fall. Journal of Wildlife Management 44: 705–709.

Sugden, L. G., and **G. Butler.** 1980. Estimating densities of breeding canvasbacks and redheads. Journal of Wildlife Management 44: 814–821.

Sugden, L. G., and **G. W. Beyersbergen.** 1984. Farming intensity on waterfowl breeding grounds in Saskatchewan parklands. Wildlife Society Bulletin 12: 22–26.

Sugden, L. G., and **G. W. Beyersbergen.** 1985. Prediction of duck nest survival in conventional and zero-tilled stubble fields. Canadian Wildlife Service Progress Notes number 156. 6 pages.

Sugden, L. G., and **G. W. Beyersbergen.** 1986. Effect of density and concealment on American crow predation of simulated duck nests. Journal of Wildlife Management 50: 9–14.

Sugden, L. G., and **G. W. Beyersbergen.** 1987. Effect of nesting cover density on American crow predation of simulated duck nests. Journal of Wildlife Management 51: 481–485.

Sugden, L. G., W. J. Thurlow, R. D. Harris, and **K. Vermeer.** 1974. Investigations of Mallards overwintering at Calgary, Alberta. Canadian Field-Naturalist 88: 303–311.

Sugden, L. G., E. A. Driver, and **M. C. S. Kingsley.** 1981. Growth and energy consumption by captive mallards. Canadian Journal of Zoology 59: 1567–1570.

Sugden, L. G., R. G. Clark, E. J. Woodsworth, and **H. Greenwood.** 1988. Use of cereal fields by foraging sandhill cranes in Saskatchewan. Journal of Applied Ecology 25: 111–124.

Swerdfager, T. M. 1990. Cooperative wildlife management: Implications for wildlife management professionals. Transactions of the North American Wildlife and Natural Resources Conference 55: 154–163.

Teeple, S. M. 1977. Reproductive success of Herring Gulls nesting on Brothers Island, Lake Ontario, in 1973. Canadian Field-Naturalist 91: 148–157.

Telfer, E. S. 1969a. Twig weight – diameter relationships for browse species. Journal of Wildlife Management 33: 917–921.

Telfer, E. S. 1969b. Weight – diameter relationships for 22 woody plant species. Canadian Journal of Botany 47: 1851–1855.

Telfer, E. S. 1972. Browse selection by deer and hares. Journal of Wildlife Management 36: 1344–1349.

Telfer, E. S. 1978. Cervid distribution, browse and snow cover in Alberta. Journal of Wildlife Management 42: 352–361.

Telfer, E. S. 1988. Habitat use by moose in southwestern Alberta. Alces 24: 14–21.

Telfer, E. S. 1992. Habitat change as a factor in the decline of the western Canadian Loggerhead Shrike, *Lanius ludovicianus*, population. Canadian Field-Naturalist 106: 321–326.

Telfer, E. S. 1994. Cattle and cervid interactions on a foothills watershed in southwestern Alberta. Canadian Field-Naturalist 108: 186–194.

Telfer, E. S., and **G. W. Scotter.** 1975. Potential for game ranching in boreal aspen forests of western Canada. Journal of Range Management 28: 172–180.

Telfer, E. S., and **J. P. Kelsall.** 1979. Studies of morphological parameters affecting ungulate locomotion in snow. Canadian Journal of Zoology 57: 2153–2159.

Telfer, E. S., and **T. C. Dauphiné.** 1981. Problems facing wildlife habitat management on Canadian forest lands. Transactions of the North American Wildlife and Natural Resources Conference 46: 358–368.

Tener, J. S. 1956. Gross composition of musk-ox milk. Canadian Journal of Zoology 34: 569–571.

Tener, J. S. 1958. The distribution of muskoxen in Canada. Journal of Mammalogy 39: 398–408.

Tener, J. S. 1963. Queen Elizabeth Islands game survey, 1961. Canadian Wildlife Service Occasional Paper number 4. 50 pages + map.

Tener, J. S. 1965. Muskoxen in Canada, a biological and taxonomic review. Canadian Wildlife Service Monograph Series number 2, 166 pages.

Tener, J. S., J. S. Hart, and **H. Pohl.** 1965. Seasonal acclimatization in varying hare (*Lepus americanus*). Canadian Journal of Zoology 43: 731–744.

Thomas, D. C. 1969. Population estimates and distribution of barren-ground caribou in Mackenzie District, N.W.T., Saskatchewan and Alberta – March to May, 1967. Canadian Wildlife Service Report Series number 9. 44 pages.

Thomas, D. C. 1982. The relationship between fertility and fat reserves of Peary caribou. Canadian Journal of Zoology 60: 597–602.

Thomas, D. C., and **E. Broughton.** 1978. Status of three Canadian caribou populations north of 70° in winter 1977. Canadian Wildlife Service Progress Notes number 85. 12 pages.

Thomas, D. C., and **P. Kroeger.** 1980. *In vitro* digestibilities of plants in rumen fluids of Peary caribou. Arctic 33: 757–767.

Thomas, D. C., and **P. Kroeger.** 1981. Digestibility of plants in ruminal fluids of barren-ground caribou. Arctic 34: 321–324.

Thomas, D. C., and **P. Everson.** 1982. Geographic variation in caribou on the Canadian arctic islands. Canadian Journal of Zoology 60: 2442–2454.

Thomas, D. C., F. L. Miller, R. H. Russell, and **G. R. Parker.** 1981. The Bailey Point region and other muskox refugia in the Canadian arctic: a short review. Arctic 34: 34–36.

Thomas, D. C., P. Kroeger, and **D. Hervieux.** 1984. *In vitro* digestibilities of plants utilized by barren-ground caribou. Arctic 37: 31–36.

Thomas, D. C., S. S. Barry, and **H. P. L. Kiliaan.** 1989. Fetal sex ratios in caribou: maternal age and condition effects. Journal of Wildlife Management 53: 885–890.

Trottier, G. C. 1986. Disruption of Rough Fescue, *Festuca hallii*, grassland by livestock grazing in Riding Mountain National Park, Manitoba. Canadian Field-Naturalist 100: 488–495.

Trottier, G. C., R. J. Breneman, and **N. A. Young.** 1980. Status and foraging distribution of White Pelicans, Prince Albert National Park, Saskatchewan. Canadian Field-Naturalist 94: 383–390.

Tuck, L. M. 1961. The murres: their distribution, populations, and ecology. Canadian Wildlife Service Monograph Series number 1, 260 pages. [incorrectly dated 1960 on title page; released 1961, as on copyright page]

Tuck, L. M. 1968. Laughing Gulls (*Larus atricilla*) and Black Skimmers (*Rhynchops nigra*) brought to Newfoundland by hurricane. Bird-Banding 39: 200–208.

Tuck, L. M. 1971. The occurrence of Greenland and European birds in Newfoundland. Bird-Banding 42: 184–209.

Tuck, L. M. 1972. The snipes: a study of the genus *Capella*. Canadian Wildlife Service Monograph Series number 5. 428 pages.

Tuck, L. M., and **H. J. Squires.** 1955. Food and feeding habits of Brunnich's Murres (*Uria lomvia lomvia*) on Akpatok Island. Journal of the Fisheries Research Board of Canada 12: 781–792.

Tuck, L. M., and **L. Lemieux.** 1959. The avifauna of Bylot Island. Dansk Ornithologisk Forenung Tidsskrift 53: 137–154.

Tuck, L. M., and **M. J. Borotra.** 1972. Additions to the avifauna of St. Pierre and Miquelon. Canadian Field-Naturalist 86: 279–284.

Turner, B. C., G. S. Hochbaum, F. D. Caswell, and **D. J. Nieman.** 1987. Agricultural impacts on wetland habitats on the Canadian prairies, 1981–1985. Transactions of the North American Wildlife and Natural Resources Conference 52: 206–215.

Turner, B., R. Tomlinson, R. Leyva, and **P. Dominguez.** 1994. Wintering populations of Lesser Snow Geese and Ross' Geese in the northern highlands of México, 1988–1990. Canadian Wildlife Service Occasional Paper number 84. 19 pages.

Vermeer, K. 1970a. Some aspects of the nesting of ducks on islands in Lake Newell, Alberta. Journal of Wildlife Management 34: 126–129.

Vermeer, K. 1970b. A study of Canada Geese, *Branta canadensis*, nesting on islands in southeastern Alberta. Canadian Journal of Zoology 48: 235–240.

Vermeer, K. 1970c. Distribution and size of colonies of white pelicans (*Pelecanus erythrorhynchos*) in Canada. Canadian Journal of Zoology 48: 1029–1032.

Vermeer, K. 1971. A survey of mercury residues in aquatic bird eggs in the Canadian Prairie Provinces. Transactions of the North American Wildlife and Natural Resources Conference 36: 138–150.

Vermeer, K. 1972. The crayfish, *Orconectis viridis*, as an indicator of mercury contamination. Canadian Field-Naturalist 86: 123–125.

Vermeer, K. 1973a. Some aspects of the breeding and mortality of Common Loons in east-central Alberta. Canadian Field-Naturalist 87: 403–408.

Vermeer, K. 1973b. Some aspects of the nesting requirements of Common Loons in Alberta. Wilson Bulletin 85: 429–435.

Vermeer, K. 1973c. Great Blue Heron and Double-crested Cormorant colonies in the Prairie Provinces. Canadian Field-Naturalist 87: 427–432.

Vermeer, K. 1979. Nesting requirements, food and breeding distribution of Rhinoceros Auklets, *Cerorhinca monocerata*, and Tufted Puffins, *Lunda cirrhata*. Ardea 67: 101–110.

Vermeer, K. 1980. The importance of timing and type of prey to reproductive success of Rhinoceros Auklets *Cerorhinca monocerata*. Ibis 122: 343–350.

Vermeer, K. 1981a. The importance of plankton to Cassin's Auklets during breeding. Journal of Plankton Research 3: 315–329.

Vermeer, K. 1981b. Food and populations of Surf Scoters in British Columbia. Wildfowl 32: 107–116.

Vermeer, K. 1982a. Comparison of the diet of the Glaucous-winged Gull on the east and west coasts of Vancouver Island. Murrelet 63: 80–85.

Vermeer, K. 1982b. Food and distribution of three *Bucephala* species in British Columbia waters. Wildfowl 33: 22–30.

Vermeer, K. 1984. The diet and food consumption of nestling Cassin's Auklets during summer, and a comparison with other plankton-feeding alcids. Murrelet 65: 65–77.

Vermeer, K., and **L. M. Reynolds.** 1970. Organochlorine residues in aquatic birds in the Canadian Prairie Provinces. Canadian Field-Naturalist 84: 117–130.

Vermeer, K., and **F. A. J. Armstrong.** 1972. Mercury in Canadian prairie ducks. Journal of Wildlife Management 36: 179–182.

Vermeer, K., and **G. Anweiler.** 1975. Oil threat to aquatic birds along the Yukon coast. Wilson Bulletin 87: 467–480.

Vermeer, K., and **R. Vermeer.** 1975. Oil threat to birds on the Canadian west coast. Canadian Field-Naturalist 89: 278–298.

Vermeer, K., and **C. D. Levings.** 1977. Populations, biomass and food habits of ducks on the Fraser River Delta intertidal area. Wildfowl 28: 49–60.

Vermeer, K., and **D. B. Peakall.** 1977. Toxic chemicals in Canadian fish-eating birds. Marine Pollution Bulletin 8: 205–210.

Vermeer, K., and **B. D. Davies.** 1978. Comparison of the breeding of Canada and Snow Geese at Westham Island, British Columbia. Wildfowl 29: 31–43.

Vermeer, K., and **L. Cullen.** 1979. Growth of Rhinoceros Auklets and Tufted Puffins. Ardea 67: 22–27.

Vermeer, K., and **D. B. Peakall.** 1979. Trace metals in seaducks of the Fraser River delta intertidal area, British Columbia. Marine Pollution Bulletin 10: 189–193.

Vermeer, K., and **N. Bourne.** 1984. The White-winged Scoter diet in British Columbia waters: resource partitioning with other scoters. Pages 30–38 *in* Marine birds: their feeding ecology and commercial fisheries relationships. *Edited by* D. N. Nettleship, G. A. Sanger, and P. F. Springer. Canadian Wildlife Service and Pacific Seabird Group.

Vermeer, K., and **L. Rankin.** 1984. Population trends in nesting Double-crested Cormorants and Pelagic Cormorants in Canada. Murrelet 65: 1–9.

Vermeer, K., and **S. J. Westrheim.** 1984. Fish changes in diets of nestling Rhinoceros Auklets and their implications. Pages 96–105 *in* Marine birds: their feeding ecology and commercial fisheries relationships. *Edited by* D. N. Nettleship, G. A. Sanger, and P. F. Springer. Canadian Wildlife Service and Pacific Seabird Group.

Vermeer, K., and **M. Lemon.** 1986. Nesting habits and habitats of Ancient Murrelets and Cassin's Auklets in the Queen Charlotte Islands, British Columbia. Murrelet 67: 33–44.

Vermeer, K., and **K. Devito.** 1988. The importance of *Paracallisoma coecus* and myctophid fishes to nesting Fork-tailed and Leach's Storm-Petrels in the Queen Charlotte Islands, British Columbia. Journal of Plankton Research 10: 63–75.

Vermeer, K., and **R. W. Butler.** *Editors.* 1989. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Canadian Wildlife Service Special Publication. 186 pages.

Vermeer, K., and **D. B. Irons.** 1991. The Glaucous-winged Gull on the Pacific coast of North America. Acta Congressus Internationalis Ornithologicus 20: 2378–2383.

Vermeer, K., and **K. H. Morgan.** *Editors.* 1997. The ecology, status, and conservation of marine and shoreline birds of the Queen Charlotte Islands. Canadian Wildlife Service Occasional Paper number 93. 148 pages.

Vermeer, K., **F. A. J. Armstrong**, and **D. R. M. Hatch.** 1973. Mercury in aquatic birds at Clay Lake, western Ontario. Journal of Wildlife Management 37: 58–61.

Vermeer, K., **R. W. Risebrough**, **A. L. Spaans**, and **L. M. Reynolds.** 1974. Pesticide effects on fishes and birds in rice fields of Surinam, South America. Environmental Pollution 7: 217–236.

Vermeer, K., **R. A. Vermeer**, **K. R. Summers**, and **R. D. Billings.** 1979. Numbers and habitat selection of Cassin's Auklets breeding on Triangle Island, British Columbia. Auk 96: 143–151.

Vermeer, K., **L. Cullen**, and **M. Porter.** 1979. A provisional explanation of the reproductive failure of Tufted Puffins (*Lunda cirrhata*) on Triangle Island, British Columbia. Ibis 121: 348–354.

Vermeer, K., **I. Robertson**, **R. W. Campbell**, **G. Kaiser**, and **M. Lemon.** 1983. Distribution and densities of marine birds on the Canadian West Coast. Canadian Wildlife Service. 73 pages.

Vermeer, K., **J. D. Fulton**, and **S. G. Sealy.** 1985. Differential use of zooplankton prey by Ancient Murrelets and Cassin's Auklets in the Queen Charlotte Islands. Journal of Plankton Research 7: 443–459.

Vermeer, K., **I. Szabo**, and **P. Greisman.** 1987. The relationship between plankton-feeding Bonaparte's and Mew gulls and tidal upwelling at Active Pass, British Columbia. Journal of Plankton Research 9: 483–501.

Vermeer, K., **D. Power**, and **G. E. J. Smith.** 1988. Habitat selection and nesting biology of roof-nesting Glaucous-winged Gulls. Colonial Waterbirds 11: 189–201.

Vermeer, K., **K. H. Morgan**, **G. E. J. Smith**, and **R. Hay.** 1989. Fall distribution of pelagic birds over the shelf off SW Vancouver Island. Colonial Waterbirds 12: 207–214.

Vermeer, K., **K. H. Morgan**, **G. E. J. Smith**, and **B. A. York.** 1991. Effects of egging on the reproductive success of Glaucous-winged Gulls. Colonial Waterbirds 14: 158–165.

Vermeer, K., **K. H. Morgan**, and **G. E. J. Smith.** 1992. Black Oystercatcher habitat selection, reproductive success and their relationship with Glaucous-winged Gulls. Colonial Waterbirds 15: 14–23.

Vermeer, K., **R. W. Butler**, and **K. H. Morgan.** *Editors.* 1992. The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island. Canadian Wildlife Service Occasional Paper number 75. 133 pages.

Vermeer, K., **K. T. Briggs**, **K. H. Morgan**, and **D. Siegel-Causey.** *Editors.* 1993. The status, ecology, and conservation of marine birds of the North Pacific. Canadian Wildlife Service Special Publication. 263 pages.

Vermeer, K., **K. H. Morgan**, and **G. E. J. Smith.** 1993. Nesting biology and predation of Pigeon Guillemots in the Queen Charlotte Islands, British Columbia. Colonial Waterbirds 16: 119–129.

Vermeer, K., **W. J. Cretney**, **J. E. Elliott**, **R. J. Norstrom**, and **P. E. Whitehead.** 1993. Elevated polychlorinated dibenzodioxin and dibenzofuran concentrations in grebes, ducks and their prey near Port Alberni, British Columbia, Canada. Marine Pollution Bulletin 26: 431–435.

Verspoor, E., T. R. Birkhead, and **D. N. Nettleship.** 1987. Incubation and brooding shift duration in the Common Murre, *Uria aalge*. Canadian Journal of Zoology 65: 247–252.

Virgo, B. B. 1971. Bird damage to sweet cherries in the Niagara Peninsula, Ontario. Canadian Journal of Plant Science 51: 415–423.

Wayland, M., and **D. K. McNicol.** 1994. Movements and survival of Common Goldeneye broods near Sudbury, Ontario, Canada. Canadian Journal of Zoology 72: 1252–1259.

Welsh, D. A., and **D. R. Fillman.** 1980. The impact of forest cutting on boreal bird populations. American Birds 34: 84–94.

Welsh, D. A., and **S. C. Lougheed.** 1996. Relationships of bird community structure and species distributions to two environmental gradients in the northern boreal forest. Ecography 19: 194–208.

Wendt, S., and **F. G. Cooch.** 1984. The kill of murres in Newfoundland in the 1977–78, 1978–79, and 1979–80 hunting seasons. Canadian Wildlife Service Progress Notes number 146. 10 pages.

Wendt, J. S., and **H. Boyd.** 1990. Goose management in Canada. Transactions of the North American Wildlife and Natural Resources Conference 55: 333–337.

Weseloh, D. V. 1984. The origins of banded Herring Gulls recovered in the Great Lakes region. Journal of Field Ornithology 55: 190–195.

Weseloh, D. V., and **P. J. Ewins.** 1994. Characteristics of a rapidly increasing colony of Double-crested Cormorants (*Phalacrocorax auritus*) in Lake Ontario: population size, reproductive parameters and band recoveries. Journal of Great Lakes Research 20: 443–456.

Weseloh, D. V., P. Mineau, and **D. J. Hallett.** 1979. Organochlorine contaminants and trends in reproduction in Great Lakes Herring Gulls, 1974–78. Transactions of the North American Wildlife and Natural Resources Conference 44: 543–557.

Weseloh, D. V., S. M. Teeple, and **M. Gilbertson.** 1983. Double-crested Cormorants of the Great Lakes: egg-laying parameters, reproductive failure, and contaminant residues in eggs, Lake Huron, 1972–1973. Canadian Journal of Zoology 61: 427–436.

Weseloh, D. V., P. Mineau, S. M. Teeple, H. Blokpoel, and **B. Ratcliff.** 1986. Colonial waterbirds nesting in Canadian Lake Huron in 1980. Canadian Wildlife Service Progress Notes number 165. 28 pages.

Weseloh, D. V., T. W. Custer, and **B. M. Braune.** 1989. Organochlorine contaminants in eggs of Common Terns from the Canadian Great Lakes, 1981. Environmental Pollution 59: 141–160.

Weseloh D. V., P. Mineau, and **J. Struger.** 1989. Geographical distribution of contaminants and productivity measures of Herring Gulls in the Great Lakes: Lake Erie and connecting channels 1978/79. Science of the Total Environment 91(1990): 141–159.

Weseloh, D. V., P. J. Ewins, and **P. Mineau.** 1992. Geographical variation in organochlorine contamination and reproductive parameters of Herring Gulls (*Larus argentatus*) in Lake Huron – 1980. Journal of Great Lakes Research 18: 316–330.

Weseloh, D. V., P. J. Ewins, J. Struger, P. Mineau, and **R. J. Norstrom.** 1994. Geographical distribution of organochlorine contaminants and reproductive parameters in Herring Gulls on Lake Superior in 1983. Environmental Monitoring and Assessment 29: 229–251.

Weseloh, D. V., J. Struger, and **C. Hebert.** 1994. White Pekin ducks (*Anas platyrhynchos*) as monitors of organochlorine and metal contamination in the Great Lakes. Journal of Great Lakes Research 20: 277–288.

Weseloh, D. V., P. J. Ewins, J. Struger, P. Mineau, C. A. Bishop, S. Postupalsky, and **J. P. Ludwig.** 1995. Double-crested Cormorants of the Great Lakes: Changes in population size, breeding distribution and reproductive output between 1913 and 1991. Pages 48–59 *in* The Double–crested Cormorant: Biology, conservation and management. *Edited by* D. N. Nettleship and D. C. Duffy. Colonial Waterbirds 18 (Special Publication 1).

Weseloh, D. V., P. Hamr, C. A. Bishop, and **R. J. Norstrom.** 1995. Organochlorine contaminant levels in waterbird species from Hamilton Harbour, Ontario: an IJC Area of Concern. Journal of Great Lakes Research 21: 121–137.

Westworth, D. A., and **E. S. Telfer.** 1993. Summer and winter bird populations associated with five age-classes of aspen forest in Alberta. Canadian Journal of Forest Research 23: 1830–1836.

Wetmore, S. P., and **D. I. Gillespie.** 1976. Osprey and Bald Eagle populations in Labrador and northeastern Quebec, 1969 to 1973. Canadian Field-Naturalist 90: 330–337.

Wetmore, S. P., R. A. Keller, and **G. E. J. Smith.** 1985. Effects of logging on bird populations in British Columbia as determined by a modified point-count method. Canadian Field-Naturalist 99: 224–233.

Whitehead, P. E., and **E. H. McEwan.** 1973. Seasonal variation in the plasma testosterone concentration of reindeer and caribou. Canadian Journal of Zoology 51: 651–658.

Whitehead, P. E., and **N. O. West.** 1977. Metabolic clearance and production rates of testosterone at different times of the year in male caribou and reindeer. Canadian Journal of Zoology 55: 1692–1697.

Whitehead, P. E., and **E. H. McEwan.** 1980. Progesterone levels in peripheral plasma of Rocky Mountain bighorn ewes (*Ovis canadensis*) during the estrous cycle and pregnancy. Canadian Journal of Zoology 58: 1105–1108.

Whitman, W. R. 1976. Impoundments for waterfowl. Canadian Wildlife Service Occasional Paper number 22. 21 pages.

Woo, M., R. D. Rowsell, and **R. G. Clark.** 1993. Hydrological classification of Canadian prairie wetlands and prediction of wetland inundation in response to climatic variability. Canadian Wildlife Service Occasional Paper number 79. 22 pages.

Wood, T. J., and **S. A. Munroe.** 1977. Dynamics of snowshoe hare populations in the Maritime Provinces. Canadian Wildlife Service Occasional Paper number 30. 19 pages.

Zhu, J., R. J. Norstrom, D. C. G. Muir, L. A. Ferron, J.–P. Weber, and **E. Dewailly.** 1995. Persistent chlorinated cyclodiene compounds in ringed seal, polar bear and human plasma from Northern Quebec, Canada: Identification and concentrations of photoheptachlor. Environmental Science & Technology 28: 267–271.

Zhu, J. P., and **R. J. Norstrom.** 1994. Identification of polychlorocamphenes (PCCs) in the Polar Bear (*Ursus maritimus*) food chain. Chemosphere 27: 1923–1935.

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A Passion for Wildlife: A History of the Canadian Wildlife Service, 1947–1997

J. ALEXANDER BURNETT

Back cover: Often something of a cliffhanger, the story of the Canadian Wildlife Service is a chronicle of a small group of men and women whose passion for wildlife has often led them to test the outer limits of Canada. The image of Don Reid, suspended by a strand of rope while banding Thick-billed Murres on Coburg Island, Northwest Territories, is an apt metaphor for CWS itself: focused, caring, and at risk in an era of profound jurisdictional and administrative change (Photo credit: P. Mineau).

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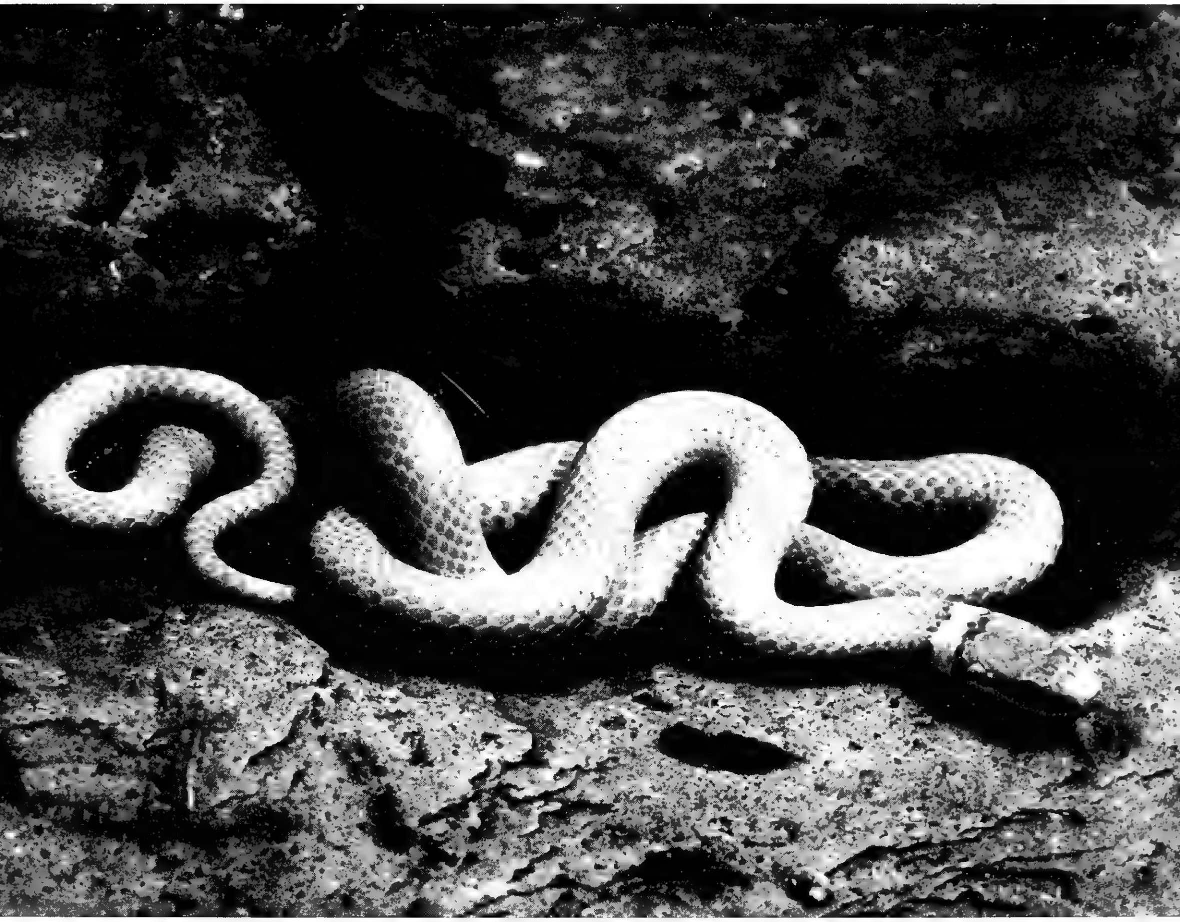

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Cover: Partial leucistic Northern Ringneck Snake, *Diadophis punctatus edwardsi*, collected at Geizer Hill, Halifax County, Nova Scotia, 28 June 1998 by Jeremy J. Broussard. Photographed by Richard Planter and enhanced on computer by Roger Lloyd (Nova Scotia Museum of Natural History slide Number RE 2425). See note by John Gilhen pages 282–284.

The Canadian Field-Naturalist

Volume 113, Number 2 April–June 1999

Organochlorine Contaminant Levels in Willow Ptarmigans, *Lagopus lagopus*, from the Western Canadian Arctic

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Wakelyn, L. A., C. C. Shank, B. T. Elkin, and D. C. Dragon. 1999. Organochlorine contaminant levels in Willow Ptarmigans, *Lagopus lagopus*, from the western Canadian arctic. Canadian Field-Naturalist 113(2): 215–220.

Baseline levels of organochlorine contaminants were established for Willow Ptarmigans (*Lagopus lagopus*) from two coastal areas in the western Canadian arctic. Egg, muscle and liver samples were tested for the presence of 21 organochlorines and 17 PCB congeners. All contaminants were below detection limits (< 0.1 ng/g for organochlorines and < 0.2 ng/g for PCB congeners) in the analysed eggs. Alpha-hexachlorocyclohexane, γ-HCH and QCB were the only compounds detected in the muscle samples. In addition to these compounds, OCS, trans-Chlordane, trans-Nonachlor, p,p^{1}-DDE, HC Epox and PCB #66/95 were detected in the liver samples. The level of contaminants detected in the ptarmigan studied was low. The implications of low-level contamination in ptarmigan and their sensitivity to contaminants is discussed in regard to their contribution to the arctic terrestrial food chain and their suitability as terrestrial ecosystem sentinel species in the Canadian Arctic.

Key Words: Willow Ptarmigan, *Lagopus lagopus*, organochlorines, PCBs, Northwest Territories.

A wide range of environmental contaminants has been detected in the Canadian arctic, many of which are not produced or used locally (Thomas et al. 1992). Although Arctic marine ecosystems have been the subject of numerous studies, there is also concern about increased levels of contaminants entering the terrestrial ecosystem, particularly in country food species. Terrestrial contaminant sources in the Canadian north include: naturally occurring metals and radionuclides associated with mineral outcrops and mining operations, metals and hydrocarbons associated with oil and gas drilling, metals and hydrocarbons emanating from the Smoking Hills on Cape Bathurst, Northwest Territories (NWT), radioactive fallout from weapons testing in previous decades and the 1986 accident at the Chernobyl nuclear power station in the Ukraine, polychlorinated biphenyl (PCB) congeners around distant early warning (DEW) line stations, and long-range transport of atmospheric pollution (Wong 1985*; Thomas et al. 1992). Wong (1985*) listed 432 waste deposit sites in the Canadian Arctic, 20 of which were considered of "great concern." Contaminants such as PCBs, dichlorodiphenylethylene (DDE), hexachlorocyclohexane (HCH), and hexachlorobenzene (HCB) are known to be present in snow, ice, air and water in some regions of the Arctic (Muir et al. 1997), and a wide range of organochlorine compounds has been shown to be carried to the Canadian arctic by long-range atmospheric transport (Barrie et al. 1992). These compounds are deposited onto plant surfaces and serve as a source of contamination to terrestrial herbivores (Thomas and Hamilton 1988*; Elkin and Bethke 1995).

The purpose of this study was to collect data on the levels of environmental contaminants in Willow Ptarmigans (*Lagopus lagopus*) in order to evaluate their present state of contamination and establish a baseline for future comparison. Adding this information to the database on contaminant levels in Arctic biota will help to assess the ptarmigan's potential use as an indicator species for monitoring terrestrial ecosystem contamination. The Willow Ptarmigan was selected because it is a year-round resident of the Northwest Territories and is abundant across the Canadian north. Seasonal movements do occur, but these migrations are generally short-range and take place within the Northwest Territories. By examining a terrestrial species that is essentially non-migratory, we can begin to assess the source and pathway of environmental contaminants within the terrestrial Arctic ecosystem.

*See Documents Cited section.

Study Area

Willow Ptarmigan hens and eggs were collected from two mainland sites in the western Canadian arctic in mid-June 1989 (Figure 1). Both collection sites were near the eastern edges of major river deltas on the Beaufort Sea coast: adjacent to the Anderson River Delta (69°42'N, 128°56'W), and 28 km southwest of the community of Tuktoyaktuk at Kittigazuit Bay (69°20'N, 133°40.5'W) east of the Mackenzie River Delta. The area surveyed was approximately 4.0 km^2 at Anderson River and 1.0 km^2 at Kittigazuit Bay. The two sites were comprised of flat areas of dwarf willow (*Salix* spp.) and Dwarf Birch (*Betula glandulosa*), interspersed with wet sedge (*Carex* spp.) and grassy areas. Willow density and height were greater at the Anderson River site whereas the Kittigazuit Bay site was primarily low shrub-graminoid tundra.

Methods

Nests were found by walking transects and flushing birds off the nest. Forty-nine eggs in total were collected from 11 clutches: 28 from Anderson River (6 clutches) and 21 from Kittigazuit Bay (5 clutches). The number of eggs collected per clutch ranged from 2 to 8 (mean = 4.45 overall, 4.67 for Anderson River, 4.20 for Kittigazuit Bay). Eight adult females were collected: three from Anderson River and five from Kittigazuit Bay. Because the initial emphasis of the study was on the collection of ptarmigan eggs for organochlorine contaminant analysis, the wildlife research permit only allowed for the collection of eight hens. Eggs were refrigerated and the carcasses were frozen prior to shipping to the laboratory. Analyses of eggs and liver and muscle tissues were conducted at the Great Lakes Institute, University of Windsor in Windsor, Ontario.

The ptarmigan samples collected were analysed in two sets. Four adult birds and 17 eggs were analysed for contaminants in 1989. The rest of the birds were analysed in 1991. The liver of one of the ptarmigan from the Kittigazuit Bay site was not analysed due to its poor condition. Two samples of both liver and muscle tissue were taken from each of the adults and, if a contaminant was detected, a mean level was derived for each tissue type. Analysis was carried out for the presence of 36 compounds, including 20 organochlorines and 17 PCB congeners. Tissues were also tested for the presence of HCB, however, residual HCB from previous analyses was detected on the laboratory equipment used to process the ptarmigan tissue samples. Because the presence of residual HCB cast doubt on the accuracy of the tissue analyses for the contaminant, the HCB data were not included in the final report. The analytical method utilized was soxhlet extraction, clean up on deactivated Florisil, and analysis of capillary GC/EC. Because of the small sample size, a blank and standard analysis was run for every five samples, and for every ten samples a replicate analysis was run. The equipment used for the analyses was able to detect organochlorine levels above 0.1 nanograms per gram (ng/g) and PCB levels above 0.2 ng/g.

Because of the small sample sizes of ptarmigan muscle and liver tissues taken, standard error was used instead of standard deviation to measure more accurately the cluster of the individual samples about the population mean. Mean contaminant levels and standard error were determined with SigmaStat version 1.0 (Jandel Scientific, 1992). Mean contaminant values are by wet weight of the original tissue sam-

TABLE 1. Arithmetic means (ng/g) of organochlorines in Willow Ptarmigan liver and muscle tissues collected from the western Canadian Arctic in June 1989[a].

	Liver Tissue[b] (n=7)		Muscle Tissue[c] (n=8)	
Contaminant	Mean	Standard Error	Mean	Standard Error
α-HCH	0.368	0.082	0.099	0.025
γ-HCH	0.116	0.066	0.061	0.011
QCB	0.129	0.039	0.103	0.021
OCS	0.104	0.035	ND[d]	—
trans-Chlordane	0.123	0.061	ND[d]	—
trans-Nonachlor	0.060	0.01	ND[d]	—
HC Epox	0.147	0.097	ND[d]	—
p,p[1]-DDE	0.699	0.159	ND[d]	—
PCB #66/95	0.123	0.023	ND[d]	—

[a]Only organochlorine compounds with detectable levels are reported here. Compounds tested with no detectable levels included: 1,2,4,5-tetrachlorobenzene and 1,2,3,4-tetrachlorobenzene, ß-hexachlorocyclohexane, oxy-Chlordane, cis-Chlordane, cis-Nonachlor, p,p[1]-DDD, p,p[1]-DDT, photo-Mirex, Mirex, Dieldrin, Arochlor 1254:1260, and polychlorinated biphenyl (PCB) congeners 28, 31, 52, 87, 99, 101, 105, 110, 118, 138, 153, 170/190, 174, 180, 182/187, and 194.
[b]Mean lipid content of liver tissue = 1.43%
[c]Mean lipid content of muscle tissue = 4.04%
[d]ND = not detectable

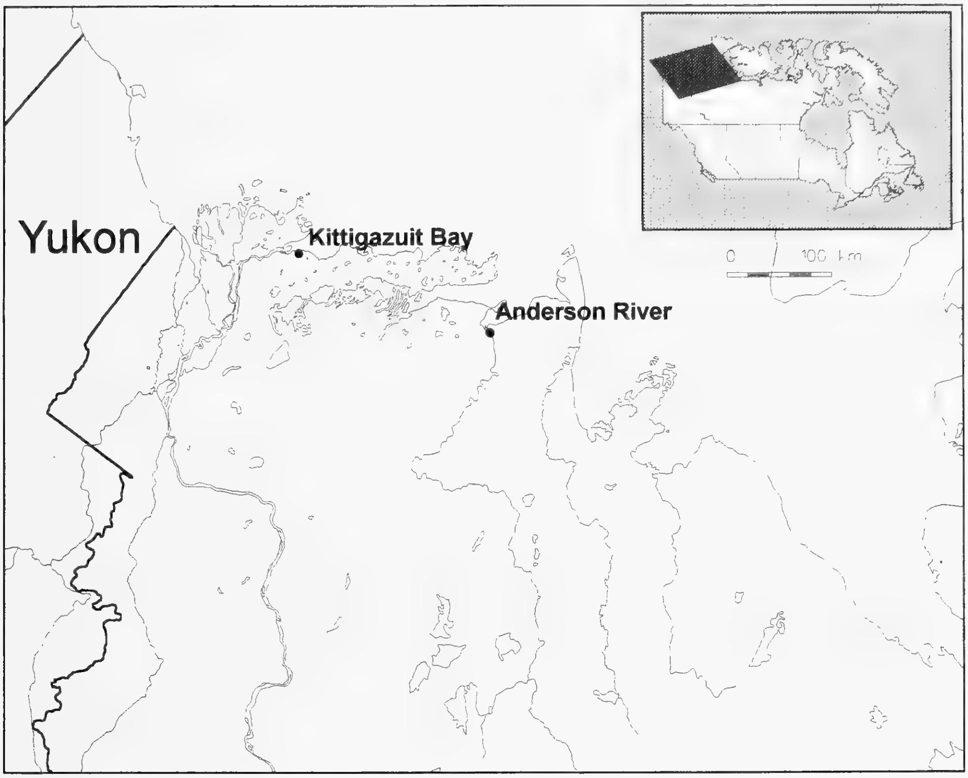

FIGURE 1. Locations of the Anderson River Delta and Kittigazuit Bay study areas in the Northwest Territories.

ple. No analysis was conducted to assess differences between sites because of the small sample sizes involved.

Results

The levels of contaminants in the ptarmigan eggs were all very low (Table 1). All contaminants for which tests were conducted were below detection limits in the initial analysis of 17 eggs in 1989 (data not shown). Because of these initial results the remainder of the eggs collected were placed in a tissue bank and were not tested.

The level of contaminants as determined by the tissue analyses were low, i.e., generally < 1.00 ng/g wet weight. The organochlorines detected in the muscle tissue were pentachlorobenzene (QCB), α-HCH, and γ-HCH (Table 1). These compounds were also detected in the liver tissues in addition to six other compounds; octachlorostyrene (OCS), trans-Chlordane, trans-Nonachlor, p,p[1]-DDE, heptachlor epoxide (HC Epox) and PCB #66/95. The concentrations of all detected contaminants were higher in liver tissue than in muscle tissue.

The predominant contaminant at both study sites was p,p[1]-DDE, with a mean concentration of 0.699 ng/g wet weight in liver. This contaminant was found in six out of seven livers sampled, with levels ranging from 0.32 to 1.19 ng/g. Contaminants from the HCH group had the second highest concentration in liver tissue with a total mean concentration of 0.53 ng/g. Alpha-hexachlorocyclohexane and γ-HCH were detected in six of the seven liver samples with a net range of 0.38 to 1.32 ng/g; the maximum being the highest contaminant level detected in any one liver. Beta-hexachlorocyclohexane was not detected in any samples. ΣHCH also had the highest concentration detected in the muscle tissue at 0.16 ng/g. The chlordane (CHL) group of contaminants had a net mean of 0.33 ng/g in the liver but were below detectable levels in the muscle samples. Chlordane-related compounds were detected in only two of the liver samples. The only PCB congener detected in the study was #66/95 and it was only found in the liver tissue of one bird at a concentration of 0.26 ng/g.

Discussion

No detectable levels of environmental contaminants were found in the ptarmigan eggs analysed in this study. Because several contaminants were detected at low levels in the hen's muscle and liver tissue, it is possible that concentrations were not high enough for the contaminants present to be incorporated into eggs at detectable levels. Ratios based on experimental work with American Kestrels (*Falco sparverius*) indicated that levels of DDE in the whole body can be twice those found in eggs (Wiemeyer et al. 1986).

The levels of contaminants in Willow Ptarmigans from our study areas in the western Arctic were similar to or lower than the levels found in tissues from Willow Ptarmigans and Rock Ptarmigans (*Lagopus mutus*) in previous studies (Thomas and Hamilton 1988*; Muir et al. 1988*). A survey of avian species in the Canadian arctic found that browsers, such as ptarmigan and grouse, contained the lowest levels of organic contaminants in their muscle tissue whereas the highest levels were found in birds feeding at upper trophic levels, particularly piscivores and molluscivores (Muir et al. 1996). Contaminant levels found in this study were all at the low end of the range reported for avian browsers.

Although direct comparison of contaminant levels between different tissue types is tenuous, the levels of DDE and PCBs observed in this report were much lower than the levels found in Rock Ptarmigan fat in Greenland (Clausen and Berg 1974) and whole body Rock and Willow ptarmigans from the Seward Peninsula (Walker 1977). One should note, however, that the Greenland study based its calculations on dry weight of the fat samples which would greatly concentrate these lipophilic contaminants and give higher values compared to this and other studies which utilize wet weights. Studies of organochlorine contaminants in Peregrine Falcon (*Falco peregrinus*) prey species showed tetraonids (the grouse family which includes ptarmigan) in northern Alberta and Rock Ptarmigan around Rankin Inlet, Northwest Territories, had the lowest levels of contamination (whole body homogenates) relative to the other prey species (Baril et al. 1990; Court et al. 1990).

It appears that, as a resident herbivore, Willow Ptarmigan in the two areas sampled are accumulating very low levels of organochlorine contaminants. This may indicate that either the amount of airborne pollution entering the terrestrial ecosystem in these areas of the Arctic is likely low, or that contaminants present in the area are not accumulating in the ptarmigan and its major food items. Willow Ptarmigans are primary browsers in the Arctic food chain, feeding on woody and herbaceous plants. The most important food source is the buds and twigs of willows which, except for late summer, comprise over 50% of the diet (Johnsgard 1983). Throughout the summer willows dominate the diet, with ptarmigan feeding on catkins and buds in June, leaves and developing fruit in July and leaves and buds in August. Birch species (*Betula* spp.) are also taken during the summer, although generally in minor amounts. Willow Ptarmigans also browse on the flowers of Mountain Avens (*Dryas integrifolia*), sedge (*Eriophorum* spp.), and buckwheat (*Rumex* spp.) and Arctic Bell Heather (*Cassiope tetragona*) when available. In the fall the ptarmigans return to a diet dominated by the buds and twigs of willow as the flower supply becomes exhausted and the leaves fall from the willows. Given the lipophilic nature of organochlorine compounds, bioaccumulation in terrestrial food chains is considerably lower than in arctic marine food chains, which are characteristically longer and comprise species with higher body-fat content (Muir et al. 1992).

Willow Ptarmigans occupy an important niche in the Arctic food chain and are an important prey species for raptors and canids. Willow Ptarmigans are the major prey item of non-migratory Gyrfalcons (*Falco rusticolus*). Roseneau (1972) reported that the species comprised over 70% by weight of the summer diet of Gyrfalcons on the Seward Peninsula in Alaska. In the winter, ptarmigans make up an even greater proportion of this raptor species' diet, as it is one of the few prey species that is neither migratory nor hibernating (Walker 1977). Snowy Owls (*Nyctea scandiaca*) also utilize Willow Ptarmigans year-round but at levels secondary to their major prey items, lemmings and mice. Other raptors which prey on Willow Ptarmigans, especially during their breeding season, include Peregrine Falcon, Golden Eagle (*Aquila chrysaetos*), Northern Harrier (*Circus cyaneus*), Rough-legged Hawk (*Buteo lagopus*), Short-eared Owl (*Asio flammeus*) and Goshawk (*Accipiter gentilis*) (Martin 1985; Hannon and Barry 1986). Canids are also major predators of Willow Ptarmigans. Ptarmigan remains have been found at the dens of Red Fox (*Vulpes vulpes*) and Arctic Fox (*Alopex lagopus*) and in Wolf (*Canis lupus*) scat (Hannon and Barry 1986). Polar Bears (*Ursus maritimus*) are also known to feed on Willow Ptarmigans (Martin 1985). Herring Gulls (*Larus argentatus*) and Parasitic Jaegers (*Stercorarius parasiticus*) have been observed to prey opportunistically on nesting hens and juvenile Willow Ptarmigans (Martin 1985; Hannon and Barry 1986). Ptarmigans are hunted year-round by the Aboriginal peoples of the Arctic with an estimated annual harvest of over 34 000 Willow and Rock Ptarmigans by resident and subsistence hunters (A. D. Hont, Northwest Territories Department of Resources, Wildlife and Economic Development, personal communication).

Low levels of organochlorine contaminants detected in ptarmigan have been considered as allowing the maintenance of healthy, viable raptor populations. Gyrfalcons did not experience the population declines associated with other North American falcon species caused by dichlorodiphenyltrichloroethane (DDT) and other organochlorine contaminants. Walker (1977) attributed this to the fact that Gyrfalcons are non-migratory and, for most of the year, preyed on resident Willow Ptarmigans which had low organochlorine contaminant burdens. Peregrine Falcons breeding in the Rankin Inlet region of the Northwest Territories were found to have relatively low organochlorine contaminant levels and a high reproductive success (Court et al. 1990). When the peregrines first arrived on their breeding grounds the only prey species available were Rock Ptarmigans and Snow Buntings (*Plectrophenax nivalis*), species that show only trace residues of organochlorines. Migratory prey species generally arrive a couple of weeks after the peregrines, and it was hypothesized that feeding on "clean" prey during this interval helped the falcons to reduce their average body burden of organochlorines before laying began, thus increasing hatching success.

For a bird species to be an effective indicator of environmental change, the bird must be sensitive to the change, and it must be possible to establish a linkage between the change in the indicator and the cause of that change. Brown and Brown (1970) compared the DDE and total DDT levels in tissues between Willow Ptarmigans from two different areas near Churchill, Manitoba. One area had been sprayed for mosquito control with DDT semi-annually from 1947 to 1954 and annually from 1955 to 1963; the other area had never been sprayed. Ptarmigan collected from the unsprayed area had concentrations of DDE and total DDT of 12 ng/g wet weight and 35 ng/g wet weight, respectively, in their livers. Ptarmigan from the sprayed area had DDE liver concentrations over 15 times that of the birds from the unsprayed area (188 ng/g wet weight) and total DDT concentrations in liver tissue nine times (337 ng/g wet weight) that of the other birds. Norwegian studies of metal contaminants in Willow Ptarmigans found varying levels of cadmium (Cd) in the birds with high levels occurring in populations in southern Norway (Fimreite et al. 1990; Kålås et al. 1991). Elevated levels of Cd were found in other Norwegian game species, but the highest levels of contamination were found in Willow and Rock ptarmigans. The studies attributed the elevated levels of Cd in game species in southern Norway to long-distance atmospheric pollution from central Europe. Kålås et al. (1991) and Wren et al. (1994) found even higher levels of Cd contamination in Willow Ptarmigans from mountainous areas in central Norway and two localized areas in northern Norway. The areas involved are highly mineralized, and the high Cd levels were believed to be caused by the natural occurrence of Cd in the soil and the release of Cd dust by mining operations in central Norway. In laboratory experiments, Fimreite (1984) demonstrated that ingested lead shot accumulates in Willow Ptarmigans, and that elevated levels can cause rapid weight loss and overt symptoms of lead poisoning with the birds appearing very dull and unthrifty. Thus, Willow Ptarmigans have been shown to be sensitive to both organochlorine and trace metal contaminants and are a potential candidate for a terrestrial ecosystem sentinel species in the Canadian arctic.

The limited geographical area of the study and small sample sizes do not permit a general statement to be made about contaminant levels in Willow Ptarmigans in the Canadian arctic. However, these data can be utilized for future comparison of organochlorine levels in ptarmigan, and they can be added to databases to establish baseline levels of contaminant data for the Arctic terrestrial ecosystem. Before a species can be considered a suitable indicator of resident terrestrial pollution, reliable baseline information on its natural state must be acquired so that comparisons of toxic levels with future studies may adequately indicate changes in levels in the environment (Wren 1986). The Willow Ptarmigan is a potential candidate for monitoring environmental loading and availability of organic and trace-metal contaminants in the Arctic terrestrial environment over time. The species is essentially non-migratory, is abundant throughout the Canadian and circumpolar arctic, and is an important food source for raptors, carnivores and humans. Willow Ptarmigans have proven sensitive to a range of contaminants. Integrating studies such as this with monitoring programs of contaminant levels in the environment will enable us to identify and track environmental contaminants in the Arctic terrestrial ecosystem and to assess their impact.

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Documents Cited (marked * after year in text)

Muir, D., C. Ford, and **B. Grift.** 1988. Analysis of dietary samples from Broughton Island (NWT) for PCBs and related organochlorine contaminants. Unpublished report, Canadian Wildlife Service.

Thomas, D. J., and **M. C. Hamilton.** 1988. Organochlorine residues in biota of the Baffin Island region. Seakem Oceanography Ltd., Sidney, British Columbia. 148 pages.

Wong, M. P. 1985. Chemical residues in fish and wildlife species harvested in northern Canada. Report for Environmental Studies Program, Northern Environment Directorate, Indian and Northern Affairs Canada. 139 pages.

Literature Cited

Baril, A., J. E. Elliott, J. D. Somers, and **G. Erickson.** 1990. Residue levels of environmental contaminants in prey species of the Peregrine Falcon (*Falco peregri-*

nus) in Canada. Canadian Field-Naturalist 104: 273–284.

Barrie, L. A., D. Gregor, B. Hargrave, R. Lake, D. Muir, R. Shearer, B. Tracey, and **T. Bidleman.** 1992. Arctic contaminants: Sources, occurrence and pathways. Science of the Total Environment 122: 1–74.

Brown, N. J., and **A. W. A. Brown.** 1970. Biological fate of DDT in a sub-arctic environment. Journal of Wildlife Management 34: 929–940.

Clausen, J., and **O. Berg.** 1974. The content of polychlorinated hydrocarbons in arctic ecosystems. The content of polychlorinated hydrocarbons in Arctic ecosystems. Pure and Applied Chemistry 42: 223–232.

Court, G. S., C. C. Gates, D. A. Boag, J. D. MacNeil, D. M. Bradley, A. C. Fesser, J. R. Patterson, G. B. Stenhouse, and **L. W. Oliphant.** 1990. A toxicological assessment of Peregrine Falcons, *Falco peregrinus tundrius*, breeding in the Keewatin District of the Northwest Territories, Canada. Canadian Field-Naturalist 104: 255–272.

Elkin, B. T., and **R. W. Bethke.** 1995. Environmental contaminants in caribou in the Northwest Territories, Canada. Science of the Total Environment 160/161: 307–321.

Fimreite, N. 1984. Effects of lead shot ingestion in willow ptarmigan. Bulletin of Environmental Contamination and Toxicology 33: 121–126.

Fimreite, N., E. K. Barth, and **A. Munkejord.** 1990. Cadmium and selenium levels in tetraonids from selected areas in Norway. Fauna Norvegica Series C., Cinclus 13: 79–84.

Hannon, S. J., and **T. W. Barry.** 1986. Demography, breeding biology and predation of willow ptarmigan at Anderson River Delta, Northwest Territories. Arctic 39: 300–303.

Johnsgard, P. A. 1983. The willow ptarmigan. Pages 169–188 *in* The Grouse of the World. University of Nebraska Press, Lincoln, Nebraska.

Kålås, J. A., H. C. Pedersen, S. Lierhagen, I. Myklebust, T. Nygård, and **E. Steinnes.** 1991. Cadmium in Norway willow ptarmigan. Pages 212–215 *in* Proceedings of the International Conference on Heavy Metals in the Environment. *Edited by* J. G. Farmer. Edinburgh UK, September 1991.

Martin, K. 1985. Herring gulls prey upon female ptarmigan. Canadian Journal of Zoology 63: 984–985.

Muir, D., B. Braune, B. DeMarch, R. Norstrom, R. Wageman, M. Gamberg, K. Poole, R. Addison, D. Bright, M. Dodd, W. Duschenko, J. Eamer, M. Evans, B. Elkin, S. Grundy, B. Hargrave, C. Hebert, R. Johnstone, K. Kidd, B. Koenig, L. Lockhart, J. Payne, J. Peddle, and **K. Reimer.** 1996. Chapter 3. Ecosystem uptake and effects. Pages 1–108 *in* Canadian Arctic Contaminants Assessment Report. *Edited by* R. Shearer. Indian and Northern Affairs Canada, Ottawa, Ontario.

Muir, D. G., R. Wageman, B. T. Hargrave, D. J. Thomas, D. B. Peakall, and **R. J. Norstrom.** 1992. Arctic marine ecosystem contamination. Science of the Total Environment 122: 75–134.

Roseneau, D. G. 1972. Summer distribution, numbers and food habits of the gyrfalcon (*Falco rusticolus* L.) on the Seward Peninsula, Alaska. M.S. thesis. University of Alaska, Fairbanks.

Thomas, D. J., B. Tracy, H. Marshall, and **R. J. Norstrom.** 1992. Arctic terrestrial ecosystem contamination. Science of the Total Environment 122: 135–164.

Walker, W. 1977. Chlorinated hydrocarbon pollutants in Alaska Gyrfalcons and their prey. Auk 94: 442–447.

Wiemeyer, S. N., R. D. Porte, G. L. Hensler and **J. R. Maestrelli.** 1986. DDE, DDT & dieldrin: Residues in American kestrels and relations to reproduction. Fish and Wildlife Technical Report. Number 6. U.S. Fish and Wildlife Service. 33 pages.

Wren, C. D. 1986. Mammals as biological monitors of environmental metal levels. Environmental Monitoring & Assessment 6: 127–144.

Wren, C. D., T. Nygård, and **E. Steinnes.** 1994. Willow Ptarmigan (*Lagopus lagopus*) as a biomonitor of environmental metal levels in Norway. Environmental Pollution 85: 291–295.

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Black Bear, *Ursus americanus*, Movements and Home Ranges on Drummond Island, Michigan

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We studied the movement patterns of 28 radio-collared Black Bears on Drummond Island, Michigan, to develop baseline knowledge on Black Bear ecology in Michigan. Adult male annual home ranges were larger than adult female annual home ranges on Drummond Island. Seasonal movements also differed among bear sex and age classes during the spring and breeding seasons; adult females with cubs moved less than other bears in the spring, and adult males moved more than other bears in the breeding season. Bear movement patterns on Drummond Island were similar to movement patterns described elsewhere in the United States, with the exception of larger adult female annual home ranges than previously described.

Key Words: Black Bear, *Ursus americanus*, home range, movements, Drummond Island, Michigan.

The Black Bear (*Ursus americanus*) is a charismatic omnivore highly prized for both recreational and aesthetic values. Historically, Black Bears were unprotected in Michigan until 1925, when declared a game animal by the state legislature (Stuewer 1957; MDNR 1988*). In 1939, the legislature removed statewide protection, but continued to allow the Natural Resources Commission to protect bears in counties that requested it. Prior to 1980, except for a brief period in the mid 1960s, bear hunters were only required to possess a deer license to harvest bears. Since 1980, a separate bear license has been required to hunt bear in Michigan. Michigan bear hunters numbered approximately 10 000 in 1985, and this number has subsequently increased (MDNR 1988*). The growing number of bear hunters has resulted in increased interest and concern over Michigan's Black Bear population (Smith 1985). In the face of these issues and problems, increased knowledge of Black Bear ecology is important to maintain optimal bear numbers and habitat.

The purpose of this study was to determine Black Bear home range sizes, home range overlap, and movement patterns on Drummond Island, Michigan. Previous studies conducted on Michigan's Black Bear population have failed to intensively study these aspects of Black Bear ecology (Erickson 1964; Rogers et al. 1976; Manville 1982). Our objectives were to (1) determine movements of bears on a daily and seasonal basis, and (2) determine bear home range sizes and home range overlap.

*See Documents Cited section.

Study Area and Methods

Study area

This study was conducted on Drummond Island, Chippewa County, Michigan, located in northern Lake Huron, 1.6 km off the eastern tip of Michigan's Upper Peninsula (46.00°N, 83.50°W). Drummond Island is 337 km^2 in size and is occupied by 800 permanent and 3000 seasonal residents (Drummond Chamber of Commerce, personal communication). Drummond Island is accessible by ferry year round, and receives heavy recreational use.

Bear hunting on Drummond Island was closed in 1982 because of concerns of overexploitation. However, a regulated permit hunt was established in September 1988. Logging and mining activities also occur on Drummond Island. Logging activities are generally concentrated at the eastern portion of the study area, while an open pit limestone mine exists at the western portion of the island. Slightly over 50% of the island is managed by the Michigan Department of Natural Resources (MDNR), Forest Management Division.

Smooth terrain is predominate on the island, with frequent rolling ground moraines and an occasional large ridge. Elevations vary from 175 to 315 m. Vegetative coverage on Drummond Island is diverse due to a variety of edaphic and anthropogenic factors. Vegetation types present on Drummond Island consisted of (Hirsch 1990): (1) 42% aspen-birch, primarily Quaking Aspen (*Populus tremuloides*), Bigtooth Aspen (*P. grandidentata*), and Paper Birch (*Betula papyrifera*) in the overstory, and Red-osier Dogwood (*Cornus stolonifera*), Roundleaf Dogwood (*C. rugosa*), Canada Buffalo-berry (*Shepherdia canadensis*), Beaked Hazel (*Corylus rostrata*), Serviceberry (*Amelanchier* spp.), Balsam Fir (*Abies balsamea*), and Northern White-cedar (*Thuja occidentalis*) in the understory; (2) 28% conifer, primarily lowland coniferous areas (cedar swamps) of Northern White-cedar with scattered Swamp Honeysuckle (*Lonicera oblongifolia*) and Speckled Alder (*Alnus rugosa*) in the understory, with lesser amounts of upland coniferous areas, predominately Red Pine (*Pinus resinosa*) with Canada Buffalo-berry, Serviceberry, and Common Juniper (*Juniperus communis*) in the understory; (3) 13% upland hardwoods, primarily American Beech (*Fagus grandifolia*) and Sugar Maple (*Acer saccharum*), with Red Raspberry (*Rubus strigosus*), American Beech, and Sugar Maple in the understory; (4) 5% openings, dominated by Wild Strawberry (*Fragaria* spp.) and grasses, with Common Chokecherry (*Prunus virginiana*) occupying the periphery; (5) 4% wetlands, including shrub swamps, mudflats, and shallow marshes; and (6) 4% lowland hardwoods, predominately Balsam Poplar (*Populus balsamifera*) and ash (*Fraxinus* spp.) with a diverse understory that included Black Spruce (*Picea mariana*), Red-osier Dogwood, Balsam Poplar, ash, and Speckled Alder. In addition, 3% of the island is comprised of residential, industrial, and recreational areas. There are two farms on the island which occupied < 1% of the total area.

Radio telemetry

Twenty-eight Black Bears were radio-collared on Drummond Island in 1987-1988 (Visser 1987*; Hirsch 1990). Radio-collared bears were located from the ground at randomly selected times throughout their daily activity period (0500 to 2300 hours) from March to December 1988. An attempt was made to locate bears at least once every two days but no more than once per day. Over 90% of bear locations were identified to < 50 meters by walking in and visually locating the bear, or by moving around the animal a minimum of three sides; 24% were exact visual locations. The remaining < 10% of locations were within 51-100 meters.

Movements and home ranges

Bear locations were plotted on a vegetation and land use coverage map of Drummond Island [Michigan Resource Inventory System (MIRIS), Land and Water Management Division, Michigan Department of Natural Resources, Lansing, Michigan] using the ARC/INFO geographic information system (Environmental Systems Research Institute, Redfield, California). Bears were categorized as adult males (n = 3), yearling males (n = 5), yearling females (n = 4), and adult females with (n = 4) and without cubs (n = 12). Bears ≥ 3 years of age were considered adults, since breeding was evident at this age.

Distances moved between consecutive locations were calculated for all locations using ARC/INFO. Locations ≥ 3 days apart were deleted from analysis. Distances moved between consecutive locations that were two days apart did not differ from distances moved in one day (P > 0.10; Mann-Whitney *U* test); thus, distances moved between locations one and two days apart were pooled and movements expressed as distances moved between successive locations.

Spring, breeding, and summer/fall time periods were separated for analysis purposes. The spring time-period occurred from den emergence to 12 June, breeding from 13 June to 13 July, and summer/fall from 14 July to denning. The start of the breeding time-period was determined on the basis of increased sightings of unmarked bears, the occurrence of family breakup, and the location of adult males and females together. Frequent dump visits by adult males marked the end of the breeding time-period. Friedman's test (Siegel 1956) and the Friedman-type simultaneous rank test (Miller 1981) were used to compare mean daily movements among time periods for a given sex and age class. The Kruskal-Wallis analysis-of-variance test (Siegel 1956) and a modified Kruskal-Wallis-type simultaneous rank test (Miller 1981) using mean ranks were used to compare mean daily movements among sex and age-classes for a given time period. We selected $a = 0.10$ for these and all other statistical tests to offset small sample sizes and the increased natural variability associated with field (vs. laboratory) studies.

The Microcomputer Program for the Analysis of Animal Locations (MCPAAL) (M. Stuwe and C. E. Blohowiak, Conservation Research Center, National Zoological Park, Smithsonian Institution, Front Royal, Virginia) was used to determine annual home range sizes for radio-collared Black Bears. Annual home range sizes were calculated with minimum convex polygons (MCP; Mohr 1947) and 95% harmonic mean contours (HM; Dixon and Chapman 1980) for adult males and females. The Mann-Whitney *U* test was utilized to test for significant differences between male and female home range sizes (Siegel 1956), while Friedman's test (Siegel 1956) was used to compare home range sizes estimated by the harmonic mean method with those estimated by the minimum convex polygon method. Annual home ranges for adult male and female bears were also delineated with ARC/INFO using the minimum convex polygon method to determine home range overlap.

Results

A total of 1846 bear radio-locations were obtained. The number of locations per bear ranged from 1 to 85 with a mean of 56 locations. Seasonal differences in mean daily movements were not

TABLE 1. Mean (S.E.) daily movements (km/day) of adult male (AM), adult female without cub (AF), adult female with cub (AF w/C), yearling male (YM), and yearling female (YF) Black Bears during spring, breeding, and summer/fall on Drummond Island, Michigan.

Bear	*Spring*	*Breeding*	*Summer/Fall*
AM	1.92(0.28)[a]	3.52(0.17)[a]	1.22(0.33)[a]
AF	1.89(0.25)[a]	2.17(0.37)[ab]	2.55(0.26)[a]
AFw/C	0.85(0.24)[b]	1.79(0.27)[ab]	1.65(0.42)[a]
YM	–	1.38(0.26)[b]	1.83(0.30)[a]
YF	–	1.29(0.19)[b]	1.52(0.39)[a]

[ab]Values sharing a letter do not differ (P>0.10).

observed within any sex and age-class (Table 1). However, significant differences were observed between sex and age-classes for the spring and breeding time periods ($P < 0.10$) (Table 1). During spring, adult females with cubs moved less per day than other sex and age-classes ($P < 0.10$) (Table 1). Adult males, during the breeding season, moved the most per day relative to all other sex and age-classes (Table 1); however, this figure was only significantly different from male and female yearlings ($P < 0.10$).

Only adult males and adult females that were monitored from den emergence in spring to denning in fall were used for home range analyses; these bears had a minimum of 42 locations per individual. Mean annual home range size for adult males [MCP = 75.64 (SE = 5.83) km^2; HM = 64.75 (SE = 12.44) km^2] and adult females [MCP = 48.14 (SE = 10.91) km^2; HM = 37.68 (SE = 8.30) km^2] did not differ when using either the MCP or HM methods. Adult female annual home ranges were significantly smaller than those of adult males when one very large (MCP = 130.00 km^2; HM = 91.33 km^2) adult female home range, which included a large portion of open water, was deleted from evaluation [new values for adult females annual home range size: MCP = 40.70 (SE = 8.74) km^2; HM = 32.80 (SE = 7.35) km^2]. For both sexes, HM annual home ranges were significantly smaller than MCP annual home ranges ($P < 0.10$). Mean percent overlap among adult males, mean percent overlap between adult males and adult females, and mean percent overlap among adult females did not differ and were 60.25% (SE = 22.02), 86.77% (SE = 1.12), and 76.92% (SE = 6.26), respectively.

Discussion

Seasonal variation in mean daily movements were not observed within any sex and age-class. However, there was a tendency for adult males to show greater daily movements during the breeding season compared to the spring and summer/fall seasons (Table 1). The small number of adult males monitored in this study might have contributed to the nonsignificant test result. Alt et al. (1976) found that adult male daily movements were greatest during the breeding season, but this was also observed for solitary females. Rogers (1987) also found that adult females increased their daily movements when in estrus. Movement data from Drummond Island could not evaluate this because adult females are in estrus for only two to three days, while our daily movement data were combined over a one-month period. Other researchers, however, believe that adult females should move less per day relative to males and occupy areas just large enough to assure adequate nutrition (Amstrup and Beecham 1976; Pelton and Burghardt 1976).

Bears on Drummond Island did show differing movement patterns within some seasons. Adult females with cubs moved shorter distances than adult females without cubs and adult males. This is likely due to the limited mobility of cubs during spring. Cubs have been found to suppress the movements of the mother for at least four months after den emergence (Lindzey and Meslow 1977; Alt et al. 1982). Adult males had the largest daily movements during the breeding time period, likely an attempt to maximize their encounters with receptive females and thus enhance their reproductive success (Rogers 1987).

Adult male home ranges tended to be larger than adult female home ranges, similar to what has been found in numerous studies elsewhere (Erickson and Petrides 1964; Jonkel and Cowan 1971; Poelker and Hartwell 1973; Alt et al. 1976; Amstrup and Beecham 1976; Lindzey and Meslow 1977; Rogers 1977; Reynolds and Beecham 1980; Garshelis and Pelton 1981; Kohn 1982; Young and Ruff 1982; Rogers 1987). The mean annual home range size for adult males (75.64 km^2) was similar to that reported from Wisconsin (71.5 km^2) (Kohn 1982), but higher than what was found in the Upper Peninsula of Michigan (51.7 km^2) (Erickson and Petrides 1964). In addition, the mean annual home range size for adult females (48.14 km^2; 40.70 km^2 excluding the aberrantly large home range) was much higher than that found in Wisconsin (13.7 km^2) (Kohn 1982) or the Upper Peninsula of Michigan (26 km^2) (Erickson and Petrides 1964). These differences may be due to a dry summer that occurred during the study period, which reduced the summer berry supply (Hirsch 1990). Pelchat and Ruff (1986) found Black Bears in Alberta to have larger home range sizes during years of food scarcity.

Home range sizes estimated by the HM method were consistently smaller than those estimated by the MCP method. A potential problem with both methods is that they assume an animal uses all areas within their home range boundary (Arthur et al. 1989). However, on Drummond Island, a home range delineated by a MCP usually included more area used for travel and more open water than one delineated by a HM (Hirsch 1990). Burt's (1943) definition of home range excludes migration routes as part of a home range. Thus, the HM method probably represents a better estimate of home range size, but the MCP method is useful for comparative purposes.

Extensive home range overlap was observed between sexes and age-classes, and among sex and age-classes. Home range overlap estimates were conservative estimates since all bears within the study area were not radio-collared. Extensive home range overlap was also found for Black Bears in New York, Idaho, Washington, Tennessee, Ontario, and North Carolina (Sauer et al. 1969; Amstrup and Beecham 1976; Lindzey and Meslow 1977; Reynolds and Beecham 1980; Garshelis and Pelton 1981; Kolenosky and Strathearn 1987; Powell 1987). However, some studies have reported territorality in adult females (Jonkel and Cowan 1971; Fuller and Keith 1980; Young and Ruff 1982; Rogers 1987). Where home range overlap occurred among bears of the same sex and age, temporal separation and agonistic encounters were occasionally observed on Drummond Island. Mutual avoidance by temporal separation was also reported by Lindzey and Meslow (1977) and Garshelis and Pelton (1981). Additionally, the amount of home range overlap observed could be a function of habitat quality. Garshelis and Pelton (1981) and Rogers (1987) both suggested that food abundance may influence the degree of home range overlap among bears. Powell (1987) observed extensive home range overlap in adult female Black Bears in North Carolina, and concluded that increased habitat productivity results in decreased territorial behavior. However, Reynolds and Beecham (1980) suggested that the patchy and unpredictable distribution of food resources in a area results in increased home range size. Subsequently, the cost of defending the home range from other bears increases to a point were defenses break down and home range overlap ensues.

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Documents Cited (marked * after date in text)

MDNR. 1988. Black bear management plan (draft). Michigan Department of Natural Resources, Wildlife Division, Lansing. 27 pages.

Visser, L. G. 1987. Drummond Island bear population. Michigan Department of Natural Resources, Pittman-Robertson Project Report W-127-R-5, Job 51.3. 5 pages.

Literature Cited

Alt, G. L., F. W. Alt, and **J. S. Lindzey**. 1976. Home range and activity patterns of black bears in northeastern Pennsylvania. Transactions of the Northeastern Section of the Wildlife Society 33: 45–46.

Alt, G. L., R. J. Aukey, D. E. Jones, and **D. C. Madl.** 1982. Movements and mortality of black bears relocated 100+ air-miles in Pennsylvania. Transactions of the Northeastern Section of the Wildlife Society 39: 16.

Amstrup, S. C., and **J. Beecham**. 1976. Activity patterns of radio collared black bears in Idaho. Journal of Wildlife Management 40: 340–348.

Arthur, S. M., W. B. Krohn, and **J. R. Gilbert**. 1989. Home range characteristics of adult fishers. Journal of Wildlife Management 53: 674–679.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24: 346–352.

Dixon, K. R., and **J. A. Chapman**. 1980. Harmonic mean measure of animal activity. Ecology 61: 1040–1044.

Erickson, A. W. 1964. Breeding biology and ecology of the black bear in Michigan. Ph.D. thesis, Michigan State University, East Lansing. 274 pages.

Erickson, A. W., and **G. A. Petrides**. 1964. Population structure, movements, and mortality of tagged black bears in Michigan. Pages 46–67 *in* The black bear in Michigan. *Edited by* A. W. Erickson, J. Nellor, and G. A. Petrides. Michigan State University Agricultural Experiment Station Research Bulletin 4. 102 pages.

Fuller, T. K., and **L. B. Keith**. 1980. Summer ranges, cover-type use, and denning of black bears near Fort McMurray, Alberta. Canadian Field-Naturalist 94: 80–83.

Garshelis, D. L., and **M. R. Pelton**. 1981. Movements of black bears in the Great Smoky Mountains National Park. Journal of Wildlife Management 45: 912–925.

Hirsch, J. G. 1990. Black bear habitat utilization and habitat model validation in Michigan. M.S. thesis, Michigan State University, East Lansing. 67 pages.

Jonkel, C. J., and **I. M. Cowan**. 1971. The black bear in the spruce-fir forest. Wildlife Monograph 27. 57 pages.

Kohn, B. E. 1982. Status and management of black bears in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 129. 31 pages.

Kolenosky, G. B., and **S. M. Strathearn**. 1987. Black bear. Pages 442–454 *in* Wild furbearer management and conservation in North America. *Edited by* M. Novak, J. A. Baker, M. E. Obbard, and B. Mallach. Ministry of Natural Resources, Ontario, Canada.

Lindzey, F. G., and **E. C. Meslow**. 1977. Home range and habitat use by black bears in southwestern Washington. Journal of Wildlife Management 41: 413–425.

Manville, A. M. 1982. Human impact on the black bear in Michigan's Lower Peninsula. Ph.D. thesis, Michigan State University, East Lansing. 188 pages.

Miller, R. G., Jr. 1981. Simultaneous statistic inference, 2nd edition. Springer-Verlag, New York, New York. 299 pages.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37: 223–249.

Pelton, M. R., and **G. M. Burghardt.** 1976. Black bears of the Smokies. Natural History 85: 54–63.

Pelchat, B. O., and **R. L. Ruff.** 1986. Habitat and spatial relationships of black bears in boreal mixedwood forest of Alberta. Proceedings of the International Conference for Bear Research and Management 6: 81–92.

Poelker, R. J., and **H. D. Hartwell.** 1973. The black bear of Washington. Washington State Game Department Biological Bulletin 14. 180 pages.

Powell, R. A. 1987. Black bear home range overlap in North Carolina and the concept of home range applied to black bears. Proceedings of the International Conference for Bear Research and Management 7: 235–242.

Reynolds, D. G., and **J. J. Beecham**. 1980. Home range activities and reproduction of black bears in west-central Idaho. Bear Biologist Association Conference Serial 3: 181–190.

Rogers, L. L. 1977. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Ph.D. thesis. University of Minnesota, Minneapolis. 194 pages.

Rogers, L. L. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. Wildlife Monograph 97. 62 pages.

Rogers, L. L., D. W. Kuehn, A. W. Erickson, E. M. Harger, L. J. Verme, and **J. J. Ozoga**. 1976. Characteristics and management of black bears that feed in garbage dumps, campgrounds, or residential areas. Proceedings of the International Conference for Bear Research and Management 3: 169–175.

Sauer, P. R., S. L. Free, and **S. D. Browne**. 1969. Movements of tagged black bears in the Adirondacks. New York Fish and Game Journal 16: 205–223.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York. 312 pages.

Smith, R. P. 1985. Are we taking too many bears? Michigan Out-of-doors 39: 64–67.

Stuewer, F. W. 1957. History of bear regulations. Michigan Department of Conservation, Game Division, Lansing. 9 pages.

Young, B. F., and **R. L. Ruff.** 1982. Population dynamics and movements of black bears in east central Alberta. Journal of Wildlife Management 46: 845–860.

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Purple Martins, *Progne subis*: A British Columbian Success Story

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The limited historical data appear to indicate that in the late 1800s and early 1900s, Purple Martin populations were limited to southern Vancouver Island from north of Campbell River south to, and including, Victoria as well as the western Fraser valley on the mainland. With the arrival of the House Sparrow, *Passer domesticus*, martin numbers appeared to suffer a decline. By the late 1940s there were only a few scattered colonies that persisted. Habitat loss (dead snag and piling removal) began to play a major role, and this, combined with an increase in the European Starling, *Sturnus vulgaris*, population, resulted in a further population decline. By 1983, known martin nests in British Columbia were fewer than six. In 1985, concerned individuals began installing nest boxes. Just over a decade later the Purple Martin population in British Columbia has grown to 146 pairs recorded in 1998.

Key Words: Purple Martin, *Progne subis*, habitat, nesting, British Columbia.

Concern regarding the status of the Purple Martin, *Progne subis*, in British Columbia (Fraser et al. 1997), combined with recent increases in the provincial population of this species, has stimulated us to review its breeding history. Contrary to published range maps and site descriptions (Fraser et al. 1997), there has never been a nest of the eastern subspecies (*Progne subis subis*) found in British Columbia. Only the western subspecies, *Progne subis arboricola*, occurs in the province and only within the Georgia Depression biogeoclimatic zone (Campbell et al. 1997).

Prior to the arrival of Europeans in North America, Purple Martins nested in abandoned woodpecker holes and similar cavities (Hill 1998). The exception (there are many) were birds using gourds erected by eastern American indigenous peoples (Wilson et al 1831; Hill 1998). Snags and abandoned woodpecker cavities in burned over areas and large clearings in the forest near wet sites were the preferred habitat (Allen and Nice 1952; Finlay 1975). Since the mid-1950s, however, there have been no published records of martins nesting in naturally occurring cavities east of the Canadian Rockies (Hill 1998).

The British Columbian population was not known to use artificial nest boxes until 1985 when a pair raised young at Cowichan Bay, near Duncan (Bryan Gates, personal communication) on Vancouver Island. By 1983, the British Columbian population had been reduced to fewer than six pairs (Fraser et al. 1997). The reduction of natural cavities due to snag cutting and piling removal had been compounded by competition for nest sites with both the introduced House Sparrow (*Passer domesticus*) and European Starling (*Sturnus vulgaris*) (Fraser et al. 1997). Since the inception of an artificial nest box program in 1985, when the first use of man-made boxes was documented, the population has increased to 146 documented breeding pairs of Purple Martins by 1998.

According to Campbell et al. (1997), Purple Martins were never abundant breeders in the province. They estimated that the maximum historical high population known was approximately 150 pairs nesting on the west coast of British Columbia.

Early Years

Pre-1960 breeding records for Purple Martins are infrequent. White (cited in Macoun 1904, pages 537–539) reported them breeding in the vicinity of Vancouver in 1894. According to Kermode (1923) they were a "common summer resident" in the Victoria area in the late 1890s but quite rare by the early 1920s, with only two to three pairs reported for several years. He also stated that since the arrival of the House Sparrow, martin numbers had "steadily declined". These observations were confirmed by Alford (1928) who stated that between 1912 and 1920 martins were a "summer resident" and were not as common as formerly. However, he did not believe that the House Sparrow then was "sufficiently common to menace this or any other species". At Nanaimo, Swarth (1912) noted martins "in considerable numbers" circling over the city and guessed thay were nesting in buildings. Martins began using "holes in pilings on log booming grounds" in 1941 or 1942 in Comox Bay (Pearce 1946). Mugens (1947) noted the return of this bird to the Victoria area after an absence of four or five years.

At the same time, in the Vancouver area, Purple Martins were nesting in downtown buildings which they continued to do until 1948 (Campbell et al. 1997). Cummings (1932) noted that they were scarce summer residents in the Fraser valley, but increasing in numbers. The last known pair to nest in the Lower Mainland was in a piling at Pitt Meadows in 1972 (Plath 1994).

The 1950s to early 1980s

From the late 1950s to very early 1980s records of Purple Martins were scattered and soon dimished across southern British Columbia.

On Vancouver Island in the Victoria area several pairs nested in ornate crevices of buildings in downtown in the 1950s and 1960s (Fraser et al. 1997). In the late 1950s, six to eight birds were seen around snags on the site of the University of Victoria before the land was cleared. In the 1960s and 1970s, martins nested in snags in the nearby Highlands including Purple Martin Pond from 1975 to 1982 (Fraser et al 1997).

At Cowichan Bay, on the east side of Duncan, they nested more or less continuously since 1972, with two to six pairs there from 1985 through 1990 (Fraser et al. 1997). In the early years, nests were in holes in pilings together with the small cavities created when three pilings came together to form a "tent" (Sid Watts, personal communication). Once single nest boxes were installed in 1985 the birds moved into these new homes. (Fraser et al. 1997).

North of Duncan, nest records show Purple Martins bred in snags around the shore of Crofton Lake, from 1970 to 1975, with two pairs in 1975 and "with the number decreasing each year" (Fraser et al. 1997).

In the 1960s, Comox Slough hosted nesting martins in "pilings left from a log sorting and booming ground" which have since rotted and fallen (Stirling personal communication). At the same time, northwest of Courtney in the vicinity of Northy Lake and Wolf Hill, Stirling (personal communication) reported martins nesting in snags. He went on to state "that it was not uncommon to see and more often hear martins overhead around Victoria and the Miracle Beach-Courtenay area", during the 1960s and early 1970s. At these sites Stirling noted "there were ongoing battles between the martins and Tree Swallows, Violet-green Swallows, and European Starlings". In 1972, in the Courtney area two pairs used pilings in a lake (Fraser et al. 1997). The next report from this area was in 1986 (two birds) and 1988 (four adults and four young) when Ed Nygren saw these birds at the Campbell River estuary (Fraser et al. 1997).

In 1959, eight pairs of Purple Martins nested at Fry Lake at the upper end of Campbell Lake just west of the town of Campbell River (Fraser et al. 1997). In the 1960s and 1970s, Stirling stated that martins nested in snags bordering an extensive marsh along the hydro line right-of-way north of Oyster River between Oyster Bay and Campbell River; in the Quinsam Lake area west of Campbell River; and during the 1960s and 1970s at least 12 martins nested in a beached ship and in pilings in Oyster Bay (Stirling, personal communication; Stirling 1961). He went on to state that the ship and pilings were later removed in a "cleanup". In 1969 Sid Watts (personal communication) saw at least 15 to 20 martins that appeared to be nesting in an old trestle at the corner of Mohun Lake, immediately north of the town of Campbell River. These pilings have since been removed.

On the mainland in the Fraser Valley in 1959 martins bred at the mouth of the Alouette River, and two years later they were reported feeding young at the mouth of the Coquitlam River (Campbell et al. 1997)

The Recovery

Table 1 illustrates the population recovery of Purple Martins in British Columbia from 1985, when

TABLE 1. Locations of Purple Martins in British Columbia. Active nests reported per year are shown.

	Year 1900s												
Colony Locations	85	86	87	88	89	90	91	92	93	94	95	96	97
Cowichan Bay	2	2	5	5+	+	6	+	+	9	12	10	22	27
Esquimalt Harbour		4	5	5	4	4	+	+	+	11	16	20	24
Ladysmith Harbour					3	4	+	4	+	13	14	11	16
Nanaimo Estuary								1	+	+	5	6	2
Newcastle Island											1	1	4+
Nanoose Bay													3
Campbell River Estuary													1
Sooke Harbour	1											1	3
West Bay Marina, Victoria										5	7	6	13
Maplewood Flats & Rocky Point										3	2	9	14
Total	3	6	10	10+	7+	14	+	5+	9+	44+	55	76	107

Note: Results from 1998 show an increase in all colonies with several new ones appearing and 146 active nests recorded.
+ active colony but exact number of nests unknown.

the first nest boxes were erected and used. All of these colonies are maintained through an active nest box program.

The stimulation for the increase in the population of Purple Martins in British Columbia came when a bird was spotted at the Cowichan Estuary near Duncan in 1980 (Bryan Gates, personal communication). A pair was spotted again here in 1984. The next year Gates and party erected several single boxes at Cowichan. On 23 July 1985 one of these boxes was reported as being occupied by Purple Martins — the first recorded pair to use a nest box in British Columbia. Since then, more single nest boxes have been provided and the colony has flourished.

In 1986, at the Navy shipyard in Esquimalt Harbour, Purple Martins were discovered nesting in portholes of a decommissioned ship: the Chaudiere (Calver Palmateer, personal communication). A nest box hung on the ship's railing was not used. Two of the four to five pairs built nests on the ocean-side of the ship. When the Navy docked the Camsell, another ship, within a metre of the Chaudiere, these clutches were deserted. The other pairs of martins that nested in portholes on the dock side of the Chaudiere fledged young (Palmateer, personal communication). In 1987 because of disturbance no young fledged from the three nests on the Chaudiere. Two additional pairs nested in another ship in the dock-yard. In 1988, 19 fledgling Purple Martins were counted, probably fleged from the ship's portholes. The ship was taken away that fall. In 1989 four pairs of martins used single nest boxes successfully (Palmateer, personal communication).

The Ladysmith colony was discovered in 1989 and the next year (1990), four adult pairs produced at least five young (Siddle et al. 1991*).

The colony in the Nanaimo Estuary was established by erecting 18 single boxes in 1992 (Bill Merilees, personal communication). Martins began nesting soon after. Five pairs were nesting in the estuary in 1995, six in 1996, and possibly two pairs in 1997. Late in 1996, 20 more single boxes were erected by Trudy Chatwin.

At Newcastle Island near Nanaimo, a pair of second-year martins attempted to enter a Violet-green Swallow (*Tachycineta thalassina*) nest box in the spring of 1995. Four single nest boxes were immediately erected and one was occupied that season. A pair nested there the following year and between four and six pairs in 1997.

In 1993, four or five single nest boxes were placed on pilings at Nanoose Bay (north of Nanaimo), and the next year, five more were erected, this time in the Campbell River Estuary (Bill Merilees, personal communication). In 1997 the Nanoose Bay boxes hosted their first recorded nesting: three breeding pairs, two in single boxes and one in the decayed top of a piling. Also in 1997, in the Campbell River Estuary, an adult male and two probable fledglings were seen sitting on a piling that held a nest box, the first sighting of Purple Martins in the area for nine years.

The first recently recorded nest of Purple Martins in Sooke Harbour was in 1985 when an adult pair fledged four young from a cavity in a piling (Fraser et al. 1997). The next record was 11 years later in 1996 when a pair nested in a single box placed there in 1990. In 1997 three nesting pairs were observed.

The major push to re-establish Purple Martins in British Columbia began in 1990 when 162 single nest boxes were placed at seven previously reported nest-sites in the southern portion of Vancouver Island. That summer 14 nests were located and 12 nestlings were banded (Walters et al. 1990; Copley and Walters 1991).

After such a successful year, it was decided to concentrate on the existing colonies: Esquimalt, West Bay (west side of the main Victoria Harbour), Cowichan and Ladysmith. In the spring of 1991 more boxes were erected, and each year thereafter. In 1995, nest boxes with eight compartments were erected at these four locations. To date almost all of the nesting pairs use single boxes, with five appartment boxes hosting a pair on either side and two having pairs on the same side. One adult female and 198 nestlings were colour-banded during the 1997 breeding season, about 75% of the total nestlings fledged on Vancouver Island that season.

In the Vancouver area, 120 single boxes were erected at several sites where the birds had once nested. These boxes were used in 1994 at Maplewood Flats in North Vancouver, with three pairs producing young, the first time in 22 years that martins were found nesting on the British Columbia mainland (Plath 1994). Maplewood Flats had two or three pairs breeding in 1995. In 1996, six nest boxes were used in Maplewood and for the first time birds nested at Rocky Point, about a mile east and around a point from Maplewood, with three pairs breeding. Fifteen nestlings were colour-banded there in 1996 (Plath 1997).

Nearby Martin Populations

A similar decline of Purple Martin numbers after the Second World War, followed by a comeback, occurred in western Washington and Oregon, but ten years earlier than in British Columbia.

Jack Davis (personal communication) of Olympia, Washington, reported that martins were once relatively numerous, but by 1976 there were no more than a dozen pairs breeding in Washington. That spring, a single nest box was erected in South Puget

*See Document Cited section.

Sound. It was immediately occupied by martins and they raised a brood. By 1980 more than a dozen pairs were nesting at this site. By 1978 other pairs were nesting in duck boxes at Ft. Lewis where more single nest boxes were then installed. Today there are several hundred pairs breeding in Washington including downtown Seattle (Davis, personal communication).

Similarily in Oregon, David Fouts (personal communication) of Portland, and others from that State report that martins were once relatively abundant in western Oregon, but their numbers had crashed by the mid-1970s. At that time a nest box program was begun by a small number of people. By 1985, when Fouts began putting up boxes, less than 100 pairs were nesting along the Lower Columbia River. In 1995, he notes that more than 400 pairs were breeding in single nest boxes on pilings along this river.

Documents Cited

Siddle, C., D. R. Copley, and **E. Walters.** 1991. Status of Purple Martin in British Columbia. Unpublished report for Wildlife Branch, British Columbia Environment Lands and Parks. 85 pages.

Literature Cited

Alford, C. E. 1928. Field notes on the birds of Vancouver Island. Ibis 4: 181–210.

Allen, R. A., and **M. M. Nice.** 1952. Study of the breeding biology of the Purple Martin (*Progne subis*). American Midland Naturalist 47: 606–665.

Campbell, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, M. C. E. McNall, and **G. E. J. Smith.** 1997. The birds of British Columbia, Volume 3, Passerines, University of British Columbia Press, Vancouver. 693 pages.

Cummings, R. A. 1932. Birds of the Vancouver district, British Columbia. Murrelet 13: 1–15.

Copley, D. R., and **E. L. Walters.** 1991. Purple Martin nest box programme summary — 1990. Victoria Naturalist 47(4): 9.

Finlay, J. C. 1975. Nesting of Purple Martins in natural cavities. Canadian Field-Naturalist 89: 454–455.

Fraser, D. F., C. Siddle, D. Copley, and **E. Walters.** 1997. Status of the Purple Martin in British Columbia. Wildlife Working Report Number WR-89. Ministry of Environment, Lands and Parks, Wildlife Branch. 28 pages.

Hill, James, III. 1998. Thanks to Native Americans, Purple Martins underwent a complete tradition shift. Purple Martin Update 8(1): 8–9.

Kermode, F. 1923. Ornithological notes. Migrant 1: 1–3.

Macoun, J. 1904. Catalogue of Canadian birds. Part 2, Sparrows, swallows, vireos, warblers, wrens, titmice, and thrushes. Geological Survey of Canada. Ottawa, Ontario. [Pages 537–539].

Meugens, A. L. 1947. Western Martin (*Progne subis hesperia*). Victoria Naturalist 3(8): 102–103.

Pearse, T. 1946. Notes on changes in bird populations in the vicinity of Comox, Vancouver Island — 1917 to 1944. Murrelet 27: 4–9.

Plath, T. 1994. Purple Martin (*Progne subis*) nest box program: first recorded nesting in 22 years for BC Mainland. Discovery, Vancouver Natural History Society 23(4): 143–145.

Plath, T. 1997. Purple Martin nest box program, 1996 update. Discovery, Vancouver Natural History Society 26(3): 109–111.

Stirling, D. 1961. Purple Martins. Victoria Naturalist 18(3): 33–34.

Swarth, H. S. 1912. Report on a collection of birds and mammals from Vancouver Island. University of California Publication in Zoology 10: 1–124.

Walters, E. L., D. R. Copley, and **S. J. Statton.** 1990. Purple Martin update — report finds fewer than 50 birds left in B.C. Victoria Naturalist 46(7): 4.

Wilson, Alexander, Charles Lucian Bonaparte, and *edited by* **Robert Jameson.** 1831. American Ornithology; or the natural history of the birds of the United States. Volume 2.

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The Muskellunge, *Esox masquinongy*, Distribution and Biology of a Recent Addition to the Ichthyofauna of New Brunswick

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The Muskellunge, *Esox masquinongy* has invaded the Saint John River of New Brunswick in the last decade. Introduced as fingerlings into a small lake in the river system in the Province of Quebec, the fish moved downstream, increasing the species' range and abundance. At least 60 fish have been collected in New Brunswick since 1988, most at hydroelectric dams in the upper and middle stretches of the river. A limited summer and winter fishery for Muskellunge has developed in a lake in the northwestern part of the province. Lengths-at-age suggest that the river fish are growing rapidly. The oldest fish was VI+. Some fish of both sexes appear to mature at age III+. The presence of young-of-the-year fish and the condition of the gonads indicate that spawning has occurred and that the muskie is capable of establishing self-sustaining local populations in the river.

Key Words: Muskellunge, *Esox masquinongy*, introduced exotic, distribution, occurrence, age and growth, Saint John River, New Brunswick.

Distributional records of fish species in New Brunswick list Chain Pickerel (*Esox niger*), introduced in the late 1800s, as the only esocid in the province (Scott and Crossman 1959; Gorham 1970). However, within the past decade Muskellunge (*Esox masquinongy*) have appeared in provincial waters. The species had not been previously documented in the Atlantic region (Scott 1967; Scott and Crossman 1973). Canadian distribution is restricted to the lakes and rivers of southern Quebec, Ontario, and eastern Manitoba. This paper reports on the recent occurrence and distribution of muskies in New Brunswick.

Discussions with fisheries officers, commercial fishermen, and fishery biologists suggest that the Muskellunge has so far invaded only the Saint John River Basin, a river system shared with the province of Quebec and the state of Maine. The occurrence of this fish in Maine and New Brunswick stems from the stocking of fingerlings in Lac Frontière, a small Quebec lake located in the headwaters of this watershed.

The Saint John River Basin

The 696 km long Saint John River flows through southeastern Quebec, northern Maine and western New Brunswick. Fifty-one percent of the 55 160 km^2 drainage area lies within New Brunswick (Figure 1). The river, from its source at Little Saint John Lake, Maine drops 482 m in elevation to the marine Bay of Fundy in New Brunswick. The river is influenced by tides in its lower 130 km but during high water discharges a considerable amount of water accumulates affecting river stages further upstream. Flooding is a characteristic phenomenon in the drainage basin (Anonymous 1972). The main stem of the river upstream from Fredericton has been extensively developed for hydro-electric power generation with dams at Mactaquac, Beechwood and Grand Falls. The river flows through a mainly forested (85%) watershed with a diversity of peaks, valleys, lakes, swampy plains, broad flood plains and rugged highlands. There are five large sub-drainages within the watershed.

Stocking History

Lac Frontière, Quebec, is a 107 ha headwater lake on the Northwest Branch of the Saint John River located near the Maine border. In 1970, fisheries personnel of Quebec Ministry of Environment and Wildlife stocked 3000 Muskellunge fingerlings in the lake, followed by another 1000 each in 1971, 1972 and 1973 and 250 in 1979 (Basley 1986*). A self-sustaining population has been established there. This presumed sedentary fish soon moved downstream into Maine waters of the Saint John River system. Angler catches in 1984 and fish collection efforts by the Maine Department of Inland Fisheries and Wildlife in 1984, 1985 and 1986 confirmed that young-of-year and yearling Muskellunge were utilizing the river system to increase range and abundance. Since 1987 a sport fishery for this species has developed in Baker Lake, Maine about 58 km south of Lac Frontière (Johnson 1987*, 1994*).

*See Documents Cited section

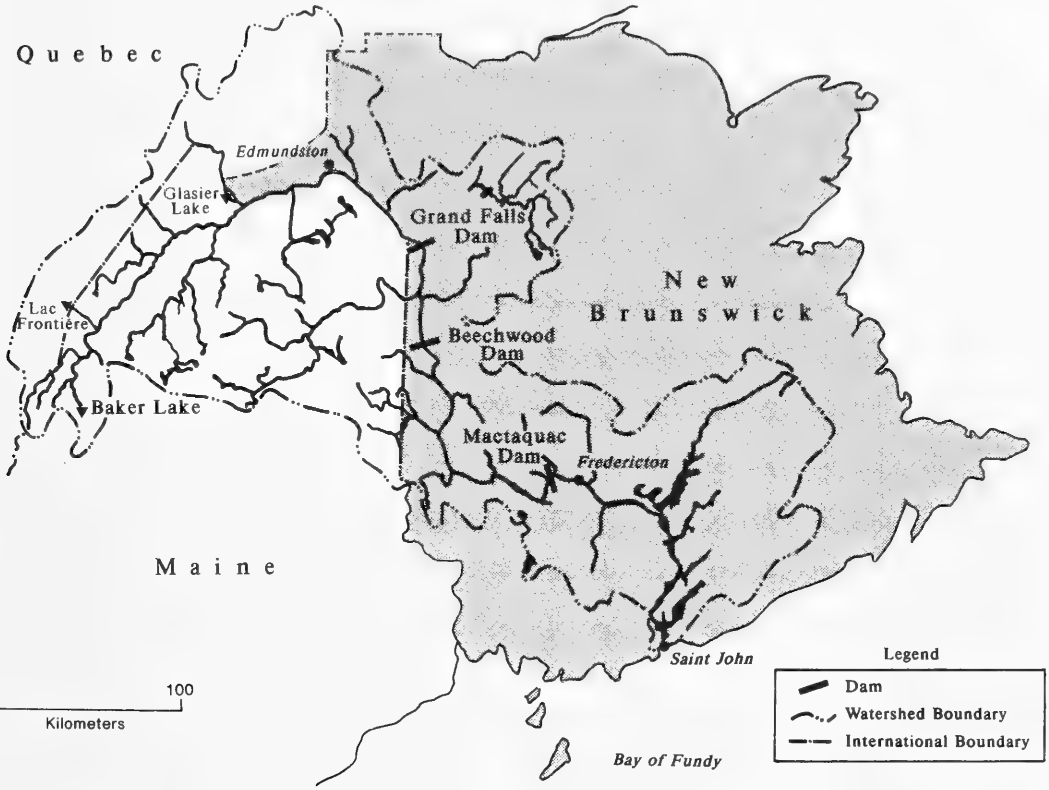

FIGURE 1. Map of the Saint John River watershed showing locations associated with Muskellunge distribution.

Occurrence and Distribution in New Brunswick

The first Muskellunge reported in New Brunswick was caught in June 1988 on the main stem of the Saint John River at the Mactaquac Dam fish collection facility operated by Canada Department of Fisheries and Oceans (Figure 1). Since then at least 47 of the more than 60 fish from the river have been collected at this facility. Sixteen of these fish have been deposited in the collections of the New Brunswick Museum, Saint John (NBM 1137, 1153-1168). Nineteen were caught at the dam in 1996. Nine were caught in the fish trap at the Beechwood Dam further upriver (Figure 1) between 1993 and 1997. Large, unidentified esocids, some in excess of 5 kg were recorded since 1990 at Beechwood which also caught the smaller Chain Pickerel. Two young-of-the-year were captured by seining and at least three more were angled. All sampled fish were collected from June to October. Biennial totals of 1, 4, 12, 12 and 29 fish taken in the Saint John in the last decade suggest an increase in numbers of some magnitude in the upper and middle stretches of the river. Very few muskies have been reported downstream from the Mactaquac Dam.

Glasier Lake, located on the Maine-New Brunswick border, has produced muskellunge for both winter and summer angling since 1992 (E. LeBlanc, personal communication). About 6 to 12 fish in the 7 to 11 kg range are taken each winter while summer angling produces about 30 to 40 fish in the 7 to 15 kg range.

Biological Data and Discussion

Lengths and/or weights were recorded for 46 Muskellunge collected from 1988 to 1997. Excluding two young-of-the-year, Muskellunge total length varied from 496 to 1040 mm (Table 1), and weight from 725 to 9100 g. Sixty-eight percent of 44 fish were between 600 and 850 mm.

Forty fish were aged using scales, with confirmation in some cases using cleithra. The oldest fish was VI+ (Table 1). The Muskellunge in the Saint John River appear to be large fish for their age but within size limits reported for the species (Carlander 1969). The only other sample of measured fish in the watershed is from Baker Lake, Maine (Johnson 1987*; S.

TABLE 1. Average size of 40 Saint John River Muskellunge, by age group, caught in New Brunswick, 1988 - 1997.

		Mean Total Length (mm)		Mean Weight (g)	
Age	Sample Size	Mean	Range	Mean	Range
0 +	1	291	-	-	-
I +	0	-	-	-	-
II +	4	583	496-622	1432	725-1680
III +	17	708	638-826	2759	1850-3700
IV +	13	780	689-934	3835	2540-6275
V +	3	907	841-960	6032	5300-6622
VI +	2	998	955-1040	8512	7924-9100

Roy, personal communication). Comparable lengths-at-age from Maine, 1988 to 1991, show that New Brunswick river muskies are growing faster than Maine lake fish, or those from the St. Lawrence River (Figure 2). However, the values for Maine angled lake fish may not be entirely comparable to New Brunswick river fish obtained by a variety of methods (mostly traps) for the years 1988 - 1997. Additionally, small sample sizes, seasonal distribution of sampling efforts and sexually dimorphic growth complicate the comparisons. But the considerable growth difference is noteworthy. The more rapid growth in younger river Muskellunge compared to lake fish has also been noted elsewhere (Harrison and Hadley 1979).

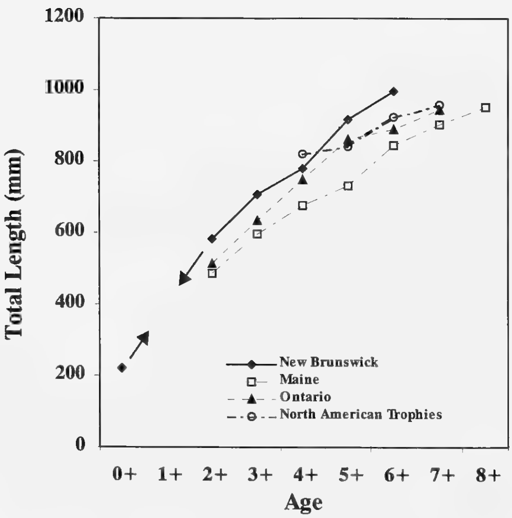

FIGURE 2. Age at growth of Muskellunge from the Saint John River, New Brunswick, 1988-1997 and growth comparisons with populations from Baker Lake, Maine (S. Roy, personal communication), St. Lawrence River, Ontario (Scott and Crossman 1973), and North American trophy fish (Casselmen and Crossman 1986).

The river fish are also heavy for their length (Figure 3). We compared length-weight relationships of New Brunswick Muskellunge to those calculated for trophy fish from North America (Casselman and Crossman 1986). New Brunswick fish, on average, weighed 11.5% more than the trophy fish for the same lengths. This above average weight may be partially attributable to samples collected in summer and fall only when fish are in prime condition. The lack of intra-specific competition based on the low numbers of Muskellunge in the watershed and the abundance of forage may also explain some of the increase in weight.

The gonads of 36 Muskellunge were visually examined; 13 were females and 6 were males, with the rest classified as unknown or immature. The smallest mature female and male were 791 and 731 mm respectively. Some fish of both sexes were maturing at age III+. The condition of the gonads and the presence of young-of-the-year fish indicate that spawning has occurred and the Muskellunge is capable of establishing self-sustaining local populations. Spawning sites, low-lying marshy areas and weedy backwaters inundated by spring floods are typical habitats in this river, especially in the lower stretches.

Stomach contents were examined in 36 Muskellunge. Fish remains were evident in 10 of the stomachs, 22 were empty and 4 had insect and vegetation remains. Since most of these muskies were caught and held in traps before processing the empty stomachs were not unexpected. It is interesting to note that a 731 mm muskie had fed on a 274 mm Alewife (*Alosa pseudoharengus*), one 861 mm muskie had ingested a 233 mm White Perch (*Morone americana*) and one 934 mm muskie had consumed a 450 mm White Sucker (*Catostomus commersoni*). The Saint John River is rich in forage fish that could be used by Muskellunge. Their primary diet will likely consist of Yellow Perch (*Perca flavescens*), White Suckers and cyprinids but they probably can feed on most fish species depending on opportunity and habitat overlap. Sport fish such as Atlantic Salmon (*Salmo salar*), Brook Trout

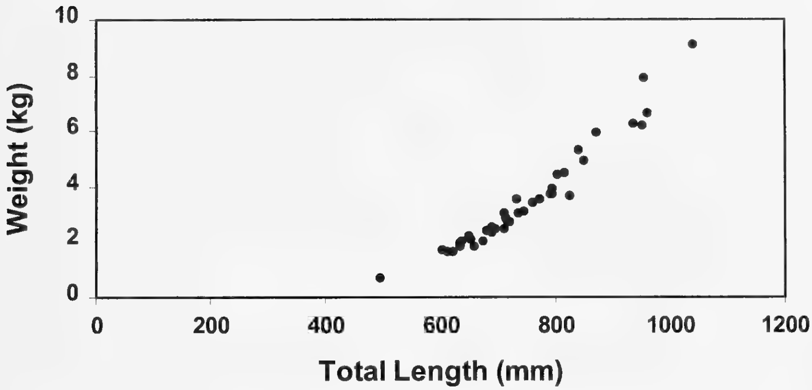

FIGURE 3. Length - weight relationship of Muskellunge from the Saint John River, New Brunswick, 1988-1997 (n = 41).

(*Salvelinius fontinalis*), and Smallmouth Bass (*Micropterus dolomieu*) are all found in this renowned salmon river. Chain Pickerel, a significant predator of newly stocked salmon and sea run smolts in some Maine lakes (Barr 1962; Warner et al. 1968), is probably an important forager on salmon smolts in the Saint John River (Washburn and Gillis 1991*). A much larger esocid, the Muskellunge could exert additional pressure on the survival of the already depleted salmon and Brook Trout stocks in the river. However, the muskie is not immune to predators as the young are prey for many species including Yellow Perch, Smallmouth Bass and sunfishes (Scott and Crossman 1973).

Muskellunge appear to adjust their foraging patterns to optimize catch. These patterns are associated with seasonal changes in environmental conditions (Miller and Menzel 1986). After spring spawning, the fish tend to behave as searching predators, as evidenced by relatively high levels of activity with extensive movements to various habitats. By late summer, the fish exhibit behavioral characteristics of a sedentary ambush predator. It is therefore assumed that downstream movements of Muskellunge from the upper Saint John River are more likely to have occurred during spring and summer.

Typical riverine habitat of the Muskellunge is deeper waters along the edge of weed beds on rocky shoals (Scott 1967) or slow stretches with submergent and emergent vegetation (Scott and Crossman 1973). Areas downstream of the Mactaquac Dam, including the Grand Lake Meadows and the Oromocto River system, are examples of this type of habitat that already support thriving Chain Pickerel populations. Although no muskies have been reported in these lower stretches of the Saint John River, the areas should provide good habitat as the fish continue to move downstream.

It is doubtful that New Brunswick anglers can effectively deplete the Muskellunge population in the Saint John River. Muskellunge populations in Escanaba Lake, Wisconsin, for example, did not exhibit trends in reduced annual harvest or population density during years with no size limits, season, or bag limits (Hoff and Serns 1986). Unrestricted angling probably cannot control population size.

The introduction of a large exotic predatory fish, such as the Muskellunge, into one of the few remaining southern salmon rivers on the eastern seaboard occurred without the knowledge of the New Brunswick government. It represents only one of the many such incidents seen throughout North America that can have a negative impact on aquatic ecosystems. In detailing the potential impacts of such introduced species, Crossman (1991) notes that at best many are a mixed blessing.

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Documents Cited (marked * after date in text)

Basley, D. J. 1986. Distribution of muskellunge in the upper Saint John River of northern Maine. Unpublished manuscript. Maine Department of Inland Fisheries and Wildlife.

Johnson, P. R. 1987. Muskellunge (*Esox masquinongy*) in Baker Lake and waters of the Saint John River. Unpublished manuscript. Progress Report Number 1. Maine Department of Inland Fisheries and Wildlife.

Johnson, P. R. 1994. Baker Lake sport fishery survey. Unpublished manuscript. Fishery Interim Summary Report Series 94–11. Maine Department of Inland Fisheries and Wildlife.

Washburn and Gillis Associated Ltd. 1991. Fishery related investigations, Mactaquac generating station (GS), minimum discharge unit. Unpublished manuscript. Fredericton, New Brunswick.

Literature Cited

Anonymous. 1972. The water sources of the Saint John River Basin. New Brunswick Inland Waters Directorate. Report S2.

Barr, L. M. 1962. A life history study of the chain pickerel (*Esox niger*) LeSueur in Beddington Lake, Maine. M.S. thesis. University of Maine, Orono. 85 pages.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, Volume 1. Iowa State University Press, Ames, Iowa.

Casselman, J. M., and **E. J. Crossman.** 1986. Size, age and growth of trophy muskellunge and muskellunge-northern pike hybrids: the cleithrum project 1979-1983. American Fisheries Society Special Publication 15: 93–110.

Crossman, E. J. 1991. Introduced freshwater fishes: A review of the North American perspective with emphasis on Canada. Canadian Journal of Fisheries and Aquatic Science 48 (Supplement 1): 46–57.

Gorham, S. W. 1970. Distributional checklist of the fishes of New Brunswick. The New Brunswick Museum. 32 pages.

Harrison, E. J., and **W. F. Hadley.** 1979. Biology of muskellunge (*Esox masquinongy*) in the Upper Niagara River. Transactions of the American Fisheries Society 108: 444–451.

Hoff, M. H., and **S. L. Serns.** 1986. The muskellunge fishery of Escanaba Lake, Wisconsin under liberalized angling regulations, 1946–1981. American Fisheries Society Special Publication 15: 249–256.

Miller, M. L., and **B. W. Menzel.** 1986. Movement, activity and habitat use patterns of muskellunge in West Okoboji Lake, Iowa. American Fisheries Society Special Publication 15: 51–61.

Scott, W. B. 1967. Freshwater fishes of eastern Canada. University of Toronto Press, Toronto. Second edition. 137 pages.

Scott, W. B., and **E. J. Crossman.** 1959. The freshwater fishes of New Brunswick: a checklist with distributional notes. Royal Ontario Museum, Division of Zoology and Palaeontology Contribution Number 51. 37 pages.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater fishes of Canada: Bulletin 184. Fisheries Research Board of Canada, Ottawa. 966 pages.

Warner, K., R. P. AuClair, S. E. DeRoche, K. A. Havey, and **C. F. Ritzi.** 1968. Fish predation on newly stocked landlocked salmon. Journal of Wildlife Management 32: 712–717.

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Additions to the Vascular Plant Flora of the Queen Charlotte Islands, British Columbia

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Lomer, Frank, and George W. Douglas. 1999. Additions to the vascular plant flora of the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 113(2): 235–240.

Fifty-two vascular plant species, new to the Queen Charlotte Islands, are discussed. The total recorded vascular flora for the islands now stands at 665.

Key Words: Native vascular plants, introduced vascular plants, rare vascular plants, new records, Queen Charlotte Islands, British Columbia, Canada.

The Queen Charlotte Islands, off the west-central coast of British Columbia, represent one of the most intriguing floristic regions in North America. The presence of glacial refugia on these and adjacent islands in British Columbia and Alaska has resulted in the existence of 10 regional endemic vascular plant taxa (Calder and Taylor 1968; Douglas 1996; Douglas et al. 1998a). Several other taxa (*Calamagrostis purpurascens* ssp. *tasuensis*, *Cassiope lycopodioides* ssp. *cristapilosa*, and *Mimulus guttatus* ssp. *haidensis*), recognized as endemics by Calder and Taylor (1968), have subsequently been reduced to synonymy by Meidinger (1990), Douglas (1991) and Greene (1994). The presence of regional endemics, major disjunctions and the presence/absence of many other species pose many questions with respect to vascular plant migration to and from the islands, before and after glaciation. These same questions are also of relevance for the non-vascular flora. The lichen and lichenicolous flora was thoroughly studied by Brodo (1995) who found 54 disjunct taxa new to British Columbia. Schofield (1989), working with the bryophyte flora, also found similar endemism and disjunction in the bryophyte flora with six endemic species and seven others that occur only on the Queen Charlotte Islands in the Western Hemisphere.

The intensive vascular plant field work conducted during the summers of 1957 and 1964 and the subsequent production of the *Flora of the Queen Charlotte Islands* (Calder and Taylor 1968) resulted in one of the most thorough floristic treatments for any region in Canada. When the study began only about 150 vascular species were known from the islands (Taylor 1989). Upon completion of the flora a total of 593 vascular taxa were documented (Calder and Taylor 1968). In the following 21 years only 18 more species were reported in the literature (Beese 1983; Roemer and Ogilvie 1983; Ogilvie and Ceska 1984; Ogilvie *et al.* 1984; Taylor 1989). Two more species, *Penstemon davidsonii* (Ogilvie 1994) and *Senecio cymbalaria* (Douglas et al. 1998b), were recently added, bringing the total Queen Charlotte Island flora to 613 vascular taxa.

During the summers of 1997 and 1998 the British Columbia Conservation Data Centre had the opportunity to conduct six weeks of field work in the Queen Charlotte Islands. The main objective of the study was to locate and document the size and condition of rare native vascular plant populations (*sensu* Douglas et al. 1998b). Twenty-five rare native vascular plants, out of a total of 38 rare plants known on the islands, were located and surveyed. In addition, three other rare plants, not previously recorded on the islands, were collected during the study. As well, a total of 49 other common species, including 30 introductions, represent new additions to the flora. Unreported collections of *Boschniakia hookeri* in the Forest Service herbarium, Smithers and Royal British Columbia Museum herbarium, Victoria, and an observation of *Chimaphila menziesii* have also been included in the present paper. The new species documented in this paper now bring the total Queen Charlotte Island vascular flora to 665 taxa. All collections are deposited in the Royal British Columbia Museum (V). Introduced species are noted with an asterisk while new rare species are indicated with a double asterisk.

Angelica genuflexa Nutt., KNEELING ANGELICA

This species is common throughout British Columbia. It was collected in a roadside ditch near the beach on the Skidegate Indian Reserve, Graham Island, 53°16′ N 132°00′ W (*Frank Lomer 97208*). A second collection was taken from a gravelly island in the Honna River, Graham Island, 53°15′ N 132°08′ W (*Frank Lomer 97408*). It was also recorded from a beach on Gospel Island in Rennell Sound, 53°23′ N 132°35′ W (*Frank Lomer 97467*).

Arrhenatherum elatius (L.) Beauv. *ex* Presl & Presl, TALL OATGRASS

An introduced species that was previously known from southern Vancouver Island and the Gulf Islands, east to southcentral British Columbia. This record was taken from a cleared, gravelly waste area along Highway 16, about 2 kilometers east of Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97231*).

Artemisia vulgaris L., COMMON MUGWORT

This exotic European species was formerly known only from southern Vancouver Island and southern British Columbia. It was collected in a horse pasture 1 km west of Sandspit, Moresby Island, 53°14′ N 132°51′ W (*Frank Lomer 97399*).

Boschniakia hookeri Walp., VANCOUVER GROUNDCONE

Vancouver Groundcone was previously known from California north along the coast to mid-Vancouver Island. A Queen Charlotte Island collection made in 1970 represents a significant northern range extension. The collection was taken in a hemlock forest and was parasitic on *Gaultheria shallon* near Newberry Cove, Moresby Island, 52°38′ N 131°26′ W (*Adolf Ceska. s.n.*) A second record, taken in 1979, was also parasitic on *Gaultheria shallon* (Salal) and was taken from Echo Harbour, Moresby Island, 52°42′ N 131°47′ W (*Sybille Haeussler & Jim Pojar 790022*).

Bromus inermis Leys. var. *inermis*, HUNGARIAN BROME

This taxon, introduced from Eurasia, occurs throughout British Columbia but is rare on the west coast. It occurred on a sandy sea dyke 3 km south of Tlell, 3 m off Highway 16, Graham Island, 53°34′ N 131°56′ W (*Frank Lomer 97214).*

Bromus vulgaris (Hook.) Shear, COLUMBIA BROME

A species previously known from southern Vancouver Island east through southern British Columbia. It was collected on a gravel roadside along Blaine Creek, 6 km south-southeast of Sandspit, Moresby Island, 53°12′ N 131°47′ W (*Frank Lomer 97403*).

Callitriche hermaphroditica L., NORTHERN WATER-STARWORT

This aquatic species was formerly known from most of southern British Columbia. It was recorded on a silty lake bottom in 30 cm of water at Skidegate Lake, Moresby Island, 53°06′ N 131°57′ W (*Frank Lomer 97547*).

Callitriche palustris L., SPRING WATER-STARWORT

This species is frequent in southern British Columbia. It was collected in standing water and in mud in a wetland area off Highway 16 just north of Chinukundl Creek, Graham Island, 53°20′ N 131°56′ W (*Frank Lomer 98259*).

Callitriche stagnalis Scop., POND WATER-STARWORT

This introduced species is infrequent in southern British Columbia. It was collected in a roadside ditch in stagnant standing water just south of Port Clements, Graham Island, 53°41′ N 132°08′ W (*Frank Lomer 98262*).

Carex lenticularis Michx. var. *dolia* (M.E. Jones) L. A. Standley, LENS-FRUITED SEDGE

This taxon is infrequent in western and southeastern British Columbia. It was collected in a dry, rocky alpine pool SE of Mount Stapleton, Graham Island, 53°14′ N 132°24′ W (*Frank Lomer 98256*).

Carex stipata Muhl. *ex* Willd., AWL-FRUITED SEDGE

This taxon was previously known from most of British Columbia south of 56°N. It was collected in a wet ditch near the Juskatla logging camp, Graham Island, 53°15′ N 132°19′ W (*Frank Lomer 97260).* A second record was taken from a swamp near Copper Creek, 14 km south of Sandspit, Moresby Island, 53°07′ N 131°41′ W (*Frank Lomer 97423*).

Chimaphila menziesii (R. Br. ex D. Don) Spreng., MENZIESII'S PIPSISSEWA

This species is considered infrequent in southwestern British Columbia. It was observed in a Sitka Spruce stand with some Red Cedar and Western Hemlock on East Limestone Island, 52°54′32.3″ N 131°36′32.2″ W (Joanna Smith, 23 June 1998).

Cichorium intybus L., CHICORY

This exotic European species is common in southern British Columbia. It was collected on a roadside in Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97553*).

Cirsium palustre (L.) Scop., MARSH THISTLE

Marsh Thistle is a rare European introduction that was previously known from only six collections scattered throughout British Columbia south of 55°N. It occurred along a logging road, with *Alnus rubra* (Red Alder), 0.5 km west of the Alliford Bay ferry towards Moresby Camp, Moresby Island, 53°12′ N 131°59′ W (*Frank Lomer 97248*).

Cotoneaster simonsii Bak., SIMONS' COTONEASTER

This Asian introduction was formerly known only from the lower mainland of British Columbia. The present collection was taken from a roadside cut near the Skidegate ferry terminal, 4 km east of Queen Charlotte City, Graham Island, 53°15′ N 132°01′ W (*Frank Lomer 97418*).

***Eleocharis parvula* (Roem. & Schult.) Link *ex* Bluff & Fingerh., SMALL SPIKE-RUSH

This rare species is currently being tracked by the British Columbia Conservation Data Centre and was previously known only from six extant sites in southwestern and southeastern British Columbia. It was first found in a muddy estuary meadow near Yakoun River, Graham Island, 53°39′ N 132°12′ W (*Frank

Lomer 97173). A second collection was made on a mud flat at the edge of a *Carex lyngbyei* (Lyngbye's Sedge) zone along the Kumdis River estuary, Graham Island, 53°41′ N 132°11′ W (*Frank Lomer 97292*).

**Euphrasia nemorosa* (Pers.) Wallr., EASTERN EYEBRIGHT

Eastern Eyebright is a European introduction that was previously documented from southern Vancouver Island and the adjacent mainland. It was collected at the edge of a rock dyke 2 km north of Masset, Graham Island, 54°01′ N 132°09′ W (*Frank Lomer 97181*). A second collection was made in a wet depression in a pasture 3.5 km south of Tlell River along Highway 16, Graham Island, 53°32′ N 132°03′ W (*Frank Lomer 97281*).

Gentiana glauca Pallas, GLAUCOUS GENTIAN

This species, frequent in the Coast Mountains, was collected in an alpine *Empetrum nigrum* (Crowberry) community. The site was located on the summit of a nameless mountain along Rennell Sound, 20 km west of Queen Charlotte City, Graham Island, 53°18′ N 132°30′ W (*Frank Lomer 97472*).

**Geranium robertianum* L., ROBERT'S GERANIUM

Robert's Geranium is frequent in southwestern British Columbia and rare farther north in the Coast Mountains. It was observed, but not collected, during this study in a roadside forest in Queen Charlotte city, Graham Island.

**Gnaphalium purpureum* L. var *purpureum,* PURPLE CUDWEED

This is a relatively common species on Vancouver Island and the adjacent mainland, introduced from more southern regions in North America. It was collected in fine gravel at the edge of a logging road west of Braverman Creek, Moresby Island, 53°00′ N 132°03′ W (*Frank Lomer 97254*).

**Juncus bulbosus* L., BULBOUS RUSH

Bulbous Rush is a European species that is rare in southwestern British Columbia. It was collected in a peaty area in a cedar-hemlock stand adjacent to the lake at Small Lake, Graham Island 53°17′ N 132°10′ W (*Frank Lomer 98232*).

**Juncus conglomeratus* L, COMPACT RUSH

Compact Rush is a European species that was previously known only from the Prince Rupert area. The first Queen Charlote Islands record came from a roadside clearing in a boggy pine-spruce forest along Wood Pile Creek, 8 km southeast of Port Clements, Graham Island, 53°41′ N 132°11′ W (*Frank Lomer 97169*). It was also collected in an overgrown cemetery in Port Clements, Graham Island, 53°41′ N 132°11′ W (*Frank Lomer 97291*).

**Lactuca muralis* (L.) Fresn., WALL LETTUCE

This European species is now widespread in southern British Columbia. It was first collected at the edge of a grassy clearing near Pallant Creek, 200 m south of Moresby Camp, Moresby Island, 53°03′ N 132°02′ W (*Frank Lomer 97251*). It was also found on a rotten log in a forest 5 km east of Queen Charlotte City, Graham Island, 53°15′ N 131°59′ W (*Frank Lomer 97414*).

Lemna minor L., COMMON DUCKWEED

This aquatic species is widespread in all but northwestern British Columbia. It was collected in a backwater pool along Tow Hill Road, 600 m west of the mouth of Chown Creek, Graham Island, 54°02′ N 132°00′ W (*Frank Lomer 97219*).

**Malva moschata* L., MUSK MALLOW

Musk Mallow is a frequent garden escape previously known in the lower Fraser Valley and southeastern British Columbia. It was growing on a rocky beach dyke and in a gravel waste area along Highway 16, 2 km east of Queen Charlotte City, Graham Island, 53°15′ N 132°07′ W (*Frank Lomer 97443*).

**Medicago lupulina* L., BLACK MEDIC

This Eurasian species is common in British Columbia south of 56°N. It was collected on a gravelly beach just above the driftwood line northeast of the Sandspit Airport, Moresby Island, 53°15′ N 131°49′ W (*Frank Lomer 97223*).

**Myosotis stricta* Link ex Roemer & Schultes, BLUE FORGET-ME-NOT

This introduced species is frequent in southern British Columbia. It was collected on a gravel roadside near Skidegate village, at Image Point, Graham Island, 53°15′ N 132°00′ W (*Frank Lomer 98213*).

Najas flexilis (Willd.) Rostk. & Schmidt, WAVY WATER NYMPH

This aquatic species is common in southern British Columbia. The present record was taken in shallow water on a sandy shoreline along Skidegate Lake, Moresby Island, 53°06′ N 131°57′ W (*Frank Lomer 97542*).

**Papaver somniferum* L, OPIUM POPPY

This species is a rare garden escape in southwestern and southcentral regions of the province. The first record was taken on a gravel pile along a dyke just northeast of the Sandspit Airport, Moresby Island, 53°15′ N 131°49′ W (*Frank Lomer 97224*). It was also collected on a coastal eroding sand dune, behind the driftwood zone, 3.5 km south of Tlell River, Graham Island, 53°32′ N 132°03′ W (*Frank Lomer 97279*).

Poa arctica R. Br. ssp. *arctica*, ARCTIC BLUEGRASS

This subalpine-alpine *Poa* occurs throughout British Columbia. It was discovered in an alpine *Carex macrochaeta* (Large-awned Sedge) community on the west side of Slatechuck Mountain, Graham Island, 53°16′ N 132°14′ W (*Frank Lomer 97357*).

Poa compressa L., CANADA BLUEGRASS
Canada Bluegrass is an infrequent species in southern British Columbia. Its native status is uncertain and it may be introduced from more southern regions in North America (Douglas et al. 1994). The record was taken from a rocky shoreline on the tidal isthmus connecting Robertson Island and Queen Charlotte City, Graham Island, 53°15′ N 132°05′ W (*Frank Lomer 97438*).

Polygonum cuspidatum Sieb. & Zucc., JAPANESE KNOTWEED
An infrequent species of moist ditches and disturbed areas mainly found in the lower Fraser Valley of the province. It was collected in a roadside ditch on the main street in Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97555*).

Potamogeton filiformis Pers., SLENDER-LEAVED PONDWEED
Elsewhere in the province, this aquatic species occurs in calcium rich ponds or lakes. It is common east of the Coast-Cascade Mountains and rare along the coast. The present record was taken in a shallow, swampy area 2 km south of the Tlell River bridge, behind the Naikoon Provincial Park Office, Graham Island, 53°34′ N 131°56′ W (*Frank Lomer 97528*).

Potamogeton foliosus Raf., CLOSED-LEAVED PONDWEED
This aquatic plant is frequent south of 55°N in British Columbia and rare farther north. The present collection was taken in a 20 to 30 cm deep stream, slowly moving through an old gravel pit, 1.3 km south of Chinukundl Creek and 100 m west of Highway 16, Graham Island, 53°19′ N 131°57′ W (*Frank Lomer 97269*).

Potamogeton praelongus, Wulfen, LONG-STALKED PONDWEED
This aquatic species was previously known from throughout most of British Columbia. The current collection was from material washed up on the north side of Skidegate Lake, Moresby Island, 53°06′ N 131°57′ W (*Frank Lomer 97544*).

Potentilla norvegica L., NORWEGIAN CINQUEFOIL
Although this species is likely native to most of British Columbia it is apparently introduced along the coast. The present record came from a cleared area in a spruce forest 2 km east of Queen Charlotte City, Graham Island, 53°15′ N 132°06′ W (*Frank Lomer 97551*).

Prunus avium (L.) L.
This species has escaped cultivation at many sites in the vicinity of Queen Charlotte City. It was not collected during this study.

Pyrola minor L., LESSER WINTERGREEN
This species is common throughout the province but had yet to be collected in the Queen Charlotte Islands. This first record was taken on a northeasterly, wet scree slope on Slatechuck Mountain, Graham Island, 53°16′ N 132°14′ W (*Frank Lomer 97354*).

Rorippa nasturtium-aquaticum (L.) Hayek, COMMON WATER CRESS
Common Water Cress is a European introduction which is common in southern British Columbia but rare northwards in the province. It was found in a clear roadside brook along Highway 16 approximately 2 km north of Lawn Hill, Graham Island, 53°25′ N 131°55′ W (*Frank Lomer 97525*).

Rorripa curvipes Greene, BLUNT-LEAVED YELLOW CRESS
This species is infrequent in southern British Columbia east of the Coast-Cascade Mountains. It was collected in dried lagoon pools in the Tlell area, Graham Island, 53°31′ N 131°57′ W (*Frank Lomer 98261*).

Rorippa sylvestris (L.) Bess., CREEPING YELLOW CRESS
Creeping Yellow Cress is a rare to frequent Euopean introduction in most of British Columbia. It was collected on a gravel bar 70 m upstream from the Yakoun River bridge, Graham Island, 53°39′ N 132°12′ W (*Frank Lomer 97530*).

Sagina saginoides (L.) Karst., ARCTIC PEARLWORT
This plant was previously known from southern Vancouver Island, the lower Fraser Valley and east of the Coast-Cascade Mountains. This first record was taken from a northerly scree slope on Slatechuck Mountain, Graham Island, 53°16′ N 132°14′ W (*Frank Lomer* 97355). A second collection was also taken from a scree slope, on Mosquito Mountain, Moresby Island, 53°01′ N 132°09′ W (*Frank Lomer 97518*).

*Salicornia maritima.*Wolff & Jeffries, EUROPEAN GLASSWORT
This introduced species is infrequent in southern British Columbia. It was collected in a disturbed area of a tidal lagoon, 54°00′ N 132°08′ W(*Frank Lomer 98268)* and in a salt marsh, 54°00′ N 132°07′ W (*Frank Lomer 98269*) near the Delkatla Wildlife Sanctuary, Masset, Graham Island.

Scirpus americanus Pers., AMERICAN BULRUSH
This is a cosmopolitan aquatic species that occurs commonly in southern British Columbia. On the Queen Charlotte Islands it was found growing on tidal sandbars and river mudflats 700 m south of the Tlell River bridge, Graham Island, 53°36′ N 131°56′ W (*Frank Lomer 97274*).

Sonchus arvensis L. var. *arvensis*, PERENNIAL SOW-THISTLE
Perennial Sow-thistle is a widespread European weed in southern British Columbia. It was collected on the main road east of Queen Charlotte City, opposite Robertson Island, Graham Island, 53°15′ N 132°05′ W (*Frank Lomer 97435*).

Sonchus oleraceus L., COMMON SOW-THISTLE

This European species was previously known along the British Columbia coast. The present record was taken from a gravelly disturbed area at the government dock, Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97411*).

**Sparganium fluctuans* (Morong) B.L. Robins., WATER BUR-REED

Water Bur-reed is an extremely rare aquatic plant, currently being tracked by the British Columbia Conservation Data Centre, and known only from three extant sites in the southwestern and central parts of the province. It was found in about one metre of water along Skidegate Lake, Moresby Island, 53°06′ N 131°157′ W (*Frank Lomer 97546*).

Spergularia rubra (L.) J. & C. Presl., RED SAND-SPURRY

This European introduction is common in southern British Columbia and rare to the north. The present record came from compacted gravel in an old gravel pit 6 km north of the Skidegate Indian Reserve, Moresby Island, 53°19′ N 131°57′ W (*Frank Lomer 97271*).

Symphytum × uplandicum Nyman, COMFREY

This distinctive, fertile hybrid is a product of two related European Comfrey species. It is infrequent in southwestern British Columbia. It was growing in a roadside ditch on Second Avenue, Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97200*).

Trifolium hybridum L., ALSIKE CLOVER

Alsike Clover is a European introduction which occurs throughout much of the province. It was collected in a cleared disturbed lot in Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97554*).

**Triglochin concinnum* Davy var. *concinnum*, GRACEFUL ARROW-GRASS

This rare species of tidal marshes occurs along both coasts of Vancouver Island as far north as Bamfield. Currently being tracked by the British Columbia Conservation Data Centre, it is only known from six extant sites. It was collected at three additional sites in the Queen Charlotte Islands. It was first found in a seepy shingle rock area along the shore 1.6 km east of Queen Charlotte City, Graham Island, 53°15′ N 132°04′ W (*Frank Lomer 97266*) and was again recorded from a slightly saline mud area in an estuary of Mud Bay creek, Gosset Bay, Moresby Island, 53°12′ N 132°15′ W (*Frank Lomer 97297*). A third collection came from the edge of a boulder stream on a mudflat at Sheldon's Lagoon, 11 km southeast of Sandspit, Moresby Island, 53°08′ N 132°45′ W (*Frank Lomer 97405*).

Vicia cracca L. TUFTED VETCH

This Eurasian introduction is common in extreme southern British Columbia and rare northward east of the Coast-Cascade Mountains. It was collected in a grassy area along the Copper Bay road, 1 km southeast of Sandspit, Moresby Island, 53°14′ N 131°48′ W (*Frank Lomer 97420*).

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Literature Cited

Beese, W. J. 1983. White Malaxis, *Malaxis monophyllos* var. *diphyllos*, an addition to the orchids of Canada from the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 97: 215–216.

Brodo, I. M. 1995. Lichens and lichenicolous fungi of the Queen Charlotte Islands, British Columbia, Canada. 1. Introduction and new records for B.C., Canada and North America. Mycotaxon LVI: 135–173.

Calder, J. A., and **R. L. Taylor.** 1968. Flora of the Queen Charlotte Islands, Part 1. Canada Department of Agriculture, Research Branch. Monograph 4. 659 pages.

Douglas, G. W. 1991. Scrophulariaceae. Pages 80–101 *in* The Vascular plants of British Columbia, Part 3. Dicotyledons (Primulaceae to Zygophyllaceae). *Edited by* G. W. Douglas, G. B. Straley, and D. Meidinger. British Columbia Ministry of Forests Special Report Series 3, Victoria. 177 pages.

Douglas, G. W. 1996. Endemic vascular plants of British Columbia and immediately adjacent regions. Canadian Field-Naturalist 110: 387–391.

Douglas, G. W., F. Lomer, and **H. L. Roemer.** 1998a. New or rediscovered vascular plant species in British Columbia. Canadian Field-Naturalist 112: 276–279.

Douglas, G. W. , G. B. Straley and **D. Meidinger.** 1998b. Rare native vascular plants of British Columbia. British Columbia Ministry of Environment, Lands and Parks, Victoria. 423 pages.

Greene, C. W. 1994. *Calamagrostis*. Pages 104–106 *in* The vascular plants of British Columbia, Part 4. Monotyledons. *Edited by* G. W. Douglas, G. B. Straley, and D. Meidinger. British Columbia Ministry of Forests Special Report Series 4, Victoria. 257 pages.

Meidinger, D. 1990. Ericaceae. Pages 6–20 *in* The vascular plants of British Columbia, Part 2. Dicotyledons (Diapensiaceae through Portulacaceae). *Edited by* G. W. Douglas, G. B. Straley, and D. Meidinger. British Columbia Ministry of Forests Special Report Series 2, Victoria. 158 pages.

Ogilvie, R. T. 1994. Rare and endemic vascular plants of Gwaii Haanas (South Moresby) Park, Queen Charlotte Islands, British Columbia. Forestry Canada, Victoria. vi+, 25 pages.

Ogilvie, R. T., and **A. Ceska.** 1984. Alpine plants of phytogeographic interest on northern Vancouver Island. Canadian Journal of Botany 62: 2356–2362.

Ogilvie, R. T., R. Hebda, and **H. Roemer.** 1984. The phytogeography of *Oxalis oregana* Nutt. in British Columbia. Canadian Journal of Botany 62: 1561–1563.

Roemer, H. L., and **R. T. Ogilvie.** 1983. Additions to the flora of the Queen Charlotte Islands on limestone. Canadian Journal of Botany 61: 2577–2580.

Scohfield, W. B. 1989. Structure and affinities of the bryoflora of the Queen Charlotte Islands. Pages 109–119 *in* The Outer Shores. Based on the proceedings of the Queen Charlotte Islands. *Edited by* G. G. E. Scudder and N. Gessler. First International Symposium, University of British Columbia, August 1984. 327 pages.

Taylor, R. L. 1989. Vascular plants of the Queen Charlotte Islands. Pages 121–125 *in* The Outer Shores. Based on the proceedings of the Queen Charlotte Islands *Edited by* G. G. E. Scudder and N. Gessler. First International Symposium, University of British Columbia, August 1984. 327 pages.

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Optimization of the Open-Hole Method for Assessing Pocket Gopher, *Thomomys* spp., Activity

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The open-hole method is widely used for monitoring activity of pocket gophers (*Thomomys* spp.) in western forests. We examined the open-hole method in a field study to optimize the number of holes to open and the number of burrow systems to observe. Sensitivity of assessing burrow system activity was minimally affected if two of three opened holes in each system were monitored, whereas there was a 20% decrease in sensitivity if only one hole was monitored. For general activity assessment purposes, a random sample of 30 burrow systems with two burrows opened per system appears to be an optimum mix to achieve sensitivity in activity estimates, without producing excessive labor in the field.

Key Words: Mazama Pocket Gophers, *Thomomys mazama*, burrow system, activity index, Oregon.

Because pocket gophers (*Thomomys* spp.) are fossorial, their activity is inferred by observing their sign. Monitoring pocket gopher activity is especially essential for forest research and management purposes, as pocket gophers are a major hindrance to natural and artificial reforestation in the western United States, probably injuring and destroying more conifer seedlings than all other animals combined (Barnes 1973; Crouch 1986; Borrecco and Black 1990). Activity levels of pocket gophers are often assessed as a means to predict the potential for population growth or invasion into reforestation units, and to determine whether damage reduction measures may be necessary or have been effective.

The open-hole method (Richens 1967; Barnes et al. 1970) provides an effective index of Pocket Gopher activity (Engeman et al. 1993). Briefly, the method involves locating a pocket gopher burrow system and opening one or more holes, then returning 48 hours later to determine whether the holes remain open or have been closed by the resident animal (Richens 1967; Barnes et al. 1970). Usually, two or three openings are created in each suspected active pocket gopher system. Pocket gophers maintain closed burrow systems and will readily plug openings in their burrows. They also lead solitary lives, so each identified system likely has one resident. Closure of any one of the burrow openings is cause for the system to be considered active.

In the present study we examined further optimization of the open-hole method. We assessed the optimal number of open holes required per burrow system to provide a reliable indicator of activity (Engeman et al. 1993). We also documented the precision of the estimated proportion of pocket gopher systems that are active within a given area when different numbers of burrow systems are sampled.

Methods

The study was conducted in southern Oregon on Ponderosa Pine (*Pinus ponderosa*) reforestation units in the Rogue River National Forest (42° 08′ N, 122° 18′ W) during the early fall of 1996. Six 2.8 ha sites (140 × 200 m) with similar age stands were selected for the study. All sites were populated with Mazama Pocket Gophers (*T. mazama*), which were the primary causal factor for seedling survival failure each of the two or three times the sites were planted within the past ten years. Each site was divided into a grid of 20 × 20 m cells to aid in the systematic examination of all pocket gopher burrow systems. Each cell was then examined and flags placed wherever there were signs of pocket gopher activity (i.e., mounds). Subsequently, we created three open-holes between the surface and the burrow system in the vicinity of each flag. After 48 hours, each opening was examined for pocket gopher activity as indicated by closure (plugged by a gopher). A burrow system was considered active if any of the three openings was observed to be closed.

The data on the number of openings plugged at each burrow system allowed us to conduct a probabilistic assessment of whether a burrow system would have been found active if only one or two of the original openings were created in the burrow system, instead of three. The assumption required for these calculations is that the outcome of plugged or unplugged for each hole in each system would have been the same whether one, two, or three of the original holes had been opened. Inferences that

TABLE 1. Number (percent) of burrows openings at each study site with 0, 1, 2, or 3 closures after 48 hours.

Site	Number of burrow openings closed				Total
	0	1	2	3	
1	10 (12.0)	7 (8.4)	32 (38.6)	34 (41.0)	83
2	3 (2.6)	14 (12.1)	29 (25.0)	70 (60.3)	116
3	2 (2.7)	6 (8.2)	29 (39.7)	36 (49.3)	73
4	4 (7.8)	7 (13.7)	10 (19.6)	30 (58.8)	51
5	15 (11.5)	21 (16.2)	39 (30.0)	55 (42.3)	130
6	13 (10.1)	16 (12.4)	44 (34.1)	56 (43.4)	129
Total	47 (8.1)	71 (12.2)	183 (31.4)	281 (48.3)	582

follow directly from this assumption include: (1) systems where all three holes were found to be closed also would have been found active if only one or two of the original three holes had been opened; (2) systems where two of the three holes were found to be closed, also would have been found active if only two of the three original holes had been opened, and two-thirds of these systems would have been found active if only one of the three original holes been opened; (3) two-thirds of those systems where only one of the three holes was closed would still have been found active if two of the original three holes had been opened, and one-third of those same systems would have been found active had only one of the original holes been opened.

We then estimated the number of burrow systems that would have been found active had we initially opened one or two of the three original holes in each system. In the following equations n_1 = number of burrow systems with one of three openings closed, n_2 = number of burrow systems with two of three openings closed, and n_3 = number of burrow systems with all three openings closed.

Number of holes opened	Number of burrow systems that would have been found active (A)
3	$A = n_3 + n_2 + n_1$
2	$A = n_3 + n_2 + n_1(0.667)$
1	$A = n_3 + n_2(0.667) + n_1(0.333)$

Besides examining the number of holes plugged within each burrow system, we also assessed precision and confidence intervals of our estimates of population activity if samples of 10, 20, 30 or 40 burrow systems had been taken at each site, rather than using all burrow systems on each of the six 2.8 ha sites.

Results

Anywhere from zero to three of the openings in each burrow system were closed by the resident pocket gopher (Table 1), but most often, all three openings were closed. Using the equations given in the Methods section, we used these data to generate

TABLE 2. Number of burrow systems at each of six sites that would have been found active if one, two or all of the original three holes had been opened. The number of active burrow systems estimated for one and two holes is followed by the percent of systems active relative to the three-hole method.

Site #	Number of burrow openings				
	3	2		1	
1	73	71	97.3%	58	79.5%
2	113	108	95.6%	94	83.2%
3	71	69	97.2%	57	80.3%
4	47	45	95.7%	39	83.0%
5	115	108	93.9%	88	76.5%
6	116	111	95.7%	91	78.4%
Total	535	511	95.5%	427	79.8%

TABLE 3. Percentage of active burrow systems at the six study sites and standard deviations associated with sample sizes of 10, 20, 30 and 40 burrow systems. The standard deviations for hypothetical activity levels ranging from 10 to 90% are also presented for these sample sizes.

Site	% Active	Standard deviation			
		n=10	n=20	n=30	n=40
1	88.0%	10.3	7.3	5.9	5.1
2	97.4%	5.0	3.6	2.9	2.5
3	97.3%	5.1	3.6	3.0	2.6
4	92.2%	8.5	6.0	4.9	4.2
5	88.5%	10.1	7.1	5.8	5.0
6	89.9%	9.5	6.7	5.5	4.8
Hypothetical	10.0%	9.5	6.7	5.5	4.7
	20.0%	12.6	8.9	7.3	6.3
	30.0%	14.5	10.2	8.4	7.2
	40.0%	15.5	11.0	8.9	7.7
	50.0%	15.8	11.2	9.1	7.9
	60.0%	15.5	11.0	8.9	7.7
	70.0%	14.5	10.2	8.4	7.2
	80.0%	12.6	8.9	7.3	6.3
	90.0%	9.5	6.7	5.5	4.7

activity assessments as if only one or two of the original three openings in the burrow systems had been made. The results, summarized across sites, are given in Table 2. In 95.5% of the cases, two openings would have provided the same assessment of activity as using three openings, whereas one opening would have provided the same activity assessment in only 79.8% of the burrow systems. We calculated the standard deviations for burrow system activity estimates for each of the six sites, as well as for hypothetical activity levels ranging from 10 to 90%, for sample sizes of 10, 20, 30 or 40 burrow systems (Table 3). While sampling more burrow systems results in a smaller standard deviation, the size of the standard deviation also is influenced by the proportion of active systems, with highest values occurring when the proportion active is at 50% (Table 3).

Discussion

Sensitivity in assessing burrow system activity was minimally affected if two of the original holes were opened (Table 2). An average of 96% of the systems found active using three holes also would have been found active had only two of those holes been used. Reducing the number of holes opened to two rather than three may be pertinent, considering that a 33% decrease in the labor applied to each system was estimated to produce only a 4% decline in sensitivity, which may be particularly important in areas where burrows are difficult to locate. Sensitivity for measuring activity, however, was estimated to drop by 20% if only one of the original three holes had been opened. Probably, this would present an unacceptable potential to underestimate activity for most research or management purposes.

The trends displayed in Table 3 are not surprising, but the values should assist decision making on the number of burrow systems that need to be sampled within a site. The greatest standard deviation (least precision) occurs when the proportion of active and inactive burrow systems nears 50%. The standard deviation decreases symmetrically as the proportion decreases or increases away from this midpoint (e.g., the precision for a proportion of 10% is the same as that for 90%). The standard deviation also is inversely proportional to the square root of the sample size. Thus, incremental increases in sample size produce diminishing benefits in precision. Activity levels such as occurred at our study sites (e.g., > 80%) result in estimates with less variation than for mid-range activities. Within the observed ranges, a random sample of 30 burrow systems, with two or three holes opened per system, is probably adequate for most applications of activity assessments. Larger sample sizes, however, may be required to obtain acceptable precision on sites with activity levels in the mid-ranges.

This paper describes relationships based on data collected from sites containing pocket gophers in cleared forest habitats, but the results may not be as applicable for other circumstances. For example, Matschke et al. (1994) determined that the open-hole method in an agricultural setting provided assessments of activity for the Townsend's Pocket Gopher (*T. townsendii*) that were biased high. Unlike the forest pocket gophers for which the open-hole activity assessment method is commonly used (*T. talpoides* and *T. mazama*), the Townsend's Pocket Gophers were not solitary in their occupancy of burrow systems (Matschke et al. 1994). Thus, Matschke et al. (1994) observed that a population reduced by strychnine bait produced nearly the same activity levels as prior to application of the toxicant (91.6% versus 97.9%). This result reinforces the principle that parameters need to be verified for untested situations prior to basing inferences on the method.

Besides testing the method in new situations, further optimization of the open-hole method is possible. As an example, the lag time between opening holes in a burrow system and rechecking them for closure is typically 24 or 48 hours, but this time period, to our knowledge, has not been optimized. Ideally the lag time should be adequate for the resident animal to plug at least one hole, but that lag time should be insufficient to allow an appreciable probability for re-invasion into unoccupied burrow systems (which can occur rapidly).

It is a common problem in wildlife biology that direct population monitoring methods are logistically complex or costly. This is especially true for fossorial animals. Here we have refined the application of an easy-to-apply and inexpensive method for monitoring pocket gophers. Improved understanding of the application parameters for this indirect observation method using sign of animal activity allows accurate inferences about population levels with minimal effort and cost.

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Literature Cited

Barnes, V. G., Jr. 1973. Pocket gophers and reforestation in the Pacific Northwest: a problem analysis. U.S. Fish and Wildlife Service Scientific Report. Wildlife 155. 18 pages.

Barnes, V. G., Jr., P. Martin, and **H. P. Tietjen.** 1970. Pocket gopher control on ponderosa pine plantations. Journal of Forestry 68: 433–435.

Borrecco, J. E., and **H. C. Black.** 1990. Animal damage problems and control activities on national forest system lands. Proceedings Vertebrate Pest Conference. Sacramento, California 14: 192–198.

Crouch, G. L. 1986. Pocket gopher damage to conifers in western forests: a historical and current perspective on the problem and its control. Proceedings Vertebrate Pest Conference. Davis, California 12: 196–198.

Engeman, R. M., D. L. Campbell, and **J. Evans**. 1993. A comparison of activity indicators for northern pocket gophers. Wildlife Society Bulletin 21: 70–73.

Matschke, G. H., R. T. Sterner, R. M. Engeman, and **J. M. O'Brien**. 1994. Limitations of open-hole and plot occupancy indices in field efficacy studies with Townsend's pocket gophers. Proceedings 15th Annual SETAC meeting. Denver, Colorado 15: 245.

Richens, V. B. 1967. The status and use of gophacide. Proceedings Vertebrate Pest Conference. San Francisco, California 3: 118–125.

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Establishment and Growth of the Lesser Snow Goose, *Chen caerulescens caerulescens*, Nesting Colony on Akimiski Island, James Bay, Northwest Territories

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Lesser Snow Geese (*Chen caerulescens caerulescens*) have nested on Akimiski Island in James Bay, Northwest Territories, Canada, since at least 1958. Nesting was intermittent until 1967, but annual after 1968. The number of nesting birds present through 1974 was usually less than 200 pairs, but has since increased tenfold. In 1994, 2218 flightless adults with 2590 goslings were present in early August, indicating about 1100 nesting pairs. In 1995, 1996, and 1997, respectively, there were an estimated 1008, 1917, and 1725 nests. Periodic dramatic increases in numbers of nesting pairs cannot be explained by recruitment alone, suggesting that immigrants, presumably delayed migrant birds from more northern colonies, remained to nest on the island. They and/or their progeny apparently developed longer term nesting affinity for the island. Both the proportion of blue morph geese, which averaged 79.6% over 39 years, and leg band recovery distribution attest to a close relationship with Cape Henrietta Maria, Ontario, and Baffin Island, Northwest Territories, nesting colonies.

Key Words: Lesser Snow Goose, *Chen caerulescens caerulescens*, nesting, colony, fidelity, immigration, James Bay.

Lesser Snow Geese, *Chen caerulescens caerulescens*, of the Mid-Continent Population in North America have increased three-fold over the last 30 years (Abraham et al. 1996). Many of these geese migrate through James Bay, Canada, in spring and fall, but relatively few nest there (Thomas and Prevett 1982). Two consequences of this dramatic population increase are expansion of existing nesting colonies and establishment of new ones (e.g., MacInnes and Kerbes 1987; Alisauskas and Boyd 1994; Kerbes 1994). In this paper, we document the establishment and growth of the world's southernmost nesting colony of Lesser Snow Geese, located on Akimiski Island, Northwest Territories (53° 11′ N, 81° 26′ W) (Figure 1).

Methods

Photographic aerial surveys of broods were conducted to measure productivity of Lesser Snow Geese nesting along the James Bay and Hudson Bay coasts in mid-summer most years between 1959 and 1986 and sporadically after that (Table 1). From 1959 to 1973, and again in 1994, a total brood census was attempted on Akimiski Island, but from 1974 to 1993 only a sample of broods was photographed to determine colour and age ratios. Oblique photographs were taken from fixed-wing (predominantly) or rotary-wing aircraft. In most years, productivity was calculated from photographs of family flocks (i.e., flocks containing several families of adults with young). In some years a few non-family flocks (i.e., containing only adults without young, and presumed to be mainly non-nesting subadults) were also photographed, but were not included in productivity calculations (Hanson et al. 1972). From 1959 through 1983, a Hasselblad camera with a 250 or 500 mm Tele-Tessar lens and black-and-white print film were used (see Hanson et al. 1972: 4 for details). From 1983 onward, a Nikon F3 camera with a 300 mm lens and either black-and-white print or colour slide film was used. Birds were tallied by colour morph (blue or white) and age (adult or gosling) directly on prints or on projected slides.

On 25 May 1994 and 31 May 1995 (incubation period), aerial surveys were flown along the shore of the island and all white-morph geese were counted while a simultaneous sample of oblique photographs was taken to document colour ratio. White-goose counts were then extrapolated using this colour ratio to obtain a total goose estimate.

Intensive ground searches were conducted on 27-30 May 1995, 5-13 June 1996, and 5-11 June 1997 in the general area of the north shore where birds had been recorded during the aerial surveys of 1994 and 1995. Local researchers' names for rivers were developed for ease of reference (Figure 1). A complete search of the area from the seaward edge of the intertidal marsh inland to the seaward edge of the tall willows was made to locate and mark all nests of Lesser Snow Geese, including destroyed nests when identifiable. Nesting areas searched on 27-30 May 1995 were revisited on 31 May 1995 to calculate an index of nests missed during the first search. Nests were

TABLE 1. Status, numbers, productivity, and percentage blue colour morph for the Lesser Snow Goose nesting colony on Akimiski Island, Northwest Territories, from 1958–1997.

Year	Status[1]	Survey Type[2]	Total[3]	Adult	Young	% Young	% Blue[4]
1958	NE	Complete	8	2	6	75.0	0.0
1959	NE	Complete	150	75	75	50.0	86.7
1960	NP	Complete	0	0	0	-	-
1961	ND	None	-	-	-	-	-
1962	NP	Complete	0	0	0	-	-
1963	MO	Complete	1	1	0	0	100.0
1964	NE	Complete	-	-	-	-	-
1965	MO	Complete	3	3	0	0	66.6
1966	NP	Complete	-	-	-	-	-
1967	NP	Complete	-	-	-	-	-
1968	NE	Complete	44	27	17	38.6	74.1
1969	NE	Complete	764	310	454	59.4	81.9
1970	NE	Complete	145	113	32	58.2	86.1
1971	NE	Complete	85	42	43	50.6	85.7
1972	NE	Complete	882	362	520	59.0	87.3
1973	NE	Complete	1982	867	1115	56.3	81.8
1974	NE	Complete	702	336	366	52.1	82.0
1976	NE	Sample	-	206	792	-	74.1
1977	NE	Sample	439	233	206	46.9	77.7
1978	NE	Sample	310	135	175	56.5	78.5
1979	NE	Banding	60	27	33	55.0	85.1
1980	NE	Sample	427	207	220	51.5	92.3
1981	NE	Sample	449	244	205	45.7	78.7
1982	NE	Sample	294	109	185	62.9	74.3
1983	NE	Sample	1026	490	536	52.2	73.9
1984	NE	Sample	291	140	151	51.9	89.3
1985	NE	Visual	-	-	-	-	-
1986	NE	Sample	199	87	112	56.3	78.2
1987	NE	Sample	38	23	12	34.3	65.2
1988	NE	Banding	71	38	33	46.4	90.1
1989	NE	Banding	15	8	7	46.6	100.0
1990	NE	Sample	7	4	3	42.9	75.0
1991	NE	Visual	-	-	-	-	-
1992	NE	Visual	-	-	-	-	-
1993	NE	Sample	95	18	31	63.3	76.6
1994	NE	Complete	4808	2218	2590	53.9	76.4
1995	NE	Nest Search	-	2016[5]	-	50.0[6]	-
1996	NE	Nest Search	-	3834[5]	-	51.7[6]	79.8
1997	NE	Nest Search	-	3450[5]	-	55.2[6]	74.9
1958-1997 Average						54.4	79.6

[1]NE = Nesting, MO = Moulting birds only, NP = None Present (but surveyed), ND = No data/no survey.
[2]Complete = Complete photo brood census; Sample = Sample photo brood survey; Banding = Banded sample of broods; Visual = Visual confirmation only; Nest Search = Intensive ground search for nests during incubation period.
[3]Total includes counts of adult/sub-adult birds in photographs in which there were no young.
[4]Percentage based on adults only from brood flock photographs (when available) or banding.
[5]Number of nests found × 2.
[6]Based on banding.

visited daily during hatch on 8-15 June 1995, 17-25 June 1996, and 12-21 June 1997 to apply web tags to goslings; nests discovered during these subsequent visits were noted and usually marked and monitored.

In several years between 1974 and 1989, flightless Lesser Snow Geese were captured and leg banded during the brood rearing period. We examined the data for Lesser Snow Geese banded on Akimiski Island and recovered from 1974 through 1992 to determine typical migration routes and wintering areas for birds from this colony.

Results

Colony Establishment and Growth

Nesting by Lesser Snow Geese on Akimiski Island was sporadic between 1958 and 1967 (Table

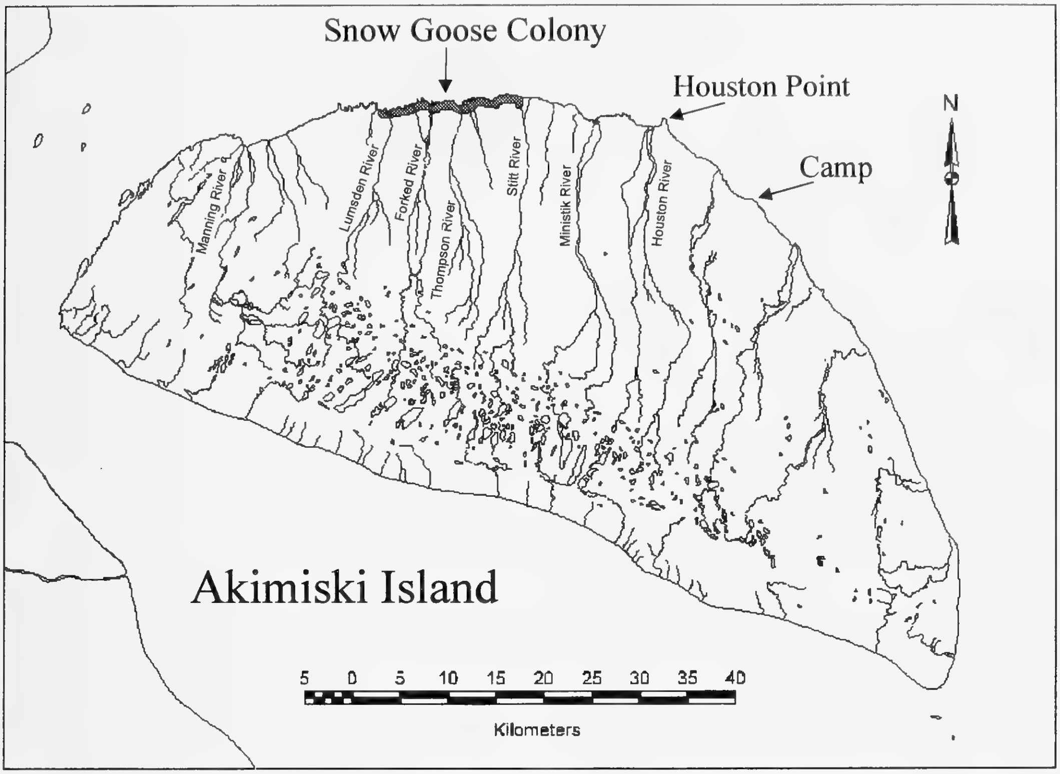

FIGURE 1. Location of Lesser Snow Goose colony and local features on Akimiski Island, Northwest Territories, in James Bay.

1); adults were present in four years but goslings in only two years of nine surveyed. A single pair with young was seen in 1958 (Boyer et al. 1958*). In 1959, up to 37 pairs nested. A few adult individuals also moulted there in 1963 and 1965 but no nesting was documented (Hanson et al. 1972). Nesting geese were detected in every year in which a survey was conducted beginning in 1968 (and there is no reason to doubt it occurred also in the years when no survey was conducted).The first substantial nesting was recorded in 1969, when 310 adults (up to 155 pairs) and 454 young were photographed. The number declined to previous levels in 1970 and 1971, when only 30 and 42 breeding adults with young, respectively, were recorded. The nesting population surged to 362 adults (up to 181 pairs) in 1972 and further to 867 adults (up to 434 pairs) in 1973. From 1974 through 1993, photographic surveys sampled rather than censused broods. Thus we know the minimum number present (i.e., those in photos) but there is no way to know what proportion of the total colony was photographed so an accurate record of breeding numbers for that period is not available.

In 1994, we attempted to determine colony size twice: the first was an aerial survey on 25 May during incubation and the second was a photographic census of families on 4 August during late brood-rearing. The May survey result was an estimate of 2155 birds, most tallied as individuals, pairs or small groups of up to six pairs, but the total included two larger flocks totalling 174, presumably non- or failed-nesters. This suggested approximately 990 potential nesting pairs. The August brood-rearing photographic census attempted complete coverage of Snow Geese present and tallied 2218 adults and 2590 goslings (up to 1109 pairs). The general similarity of results suggested that the May survey measured only nesting pairs and associated yearlings, non- and failed-nesting adults (with no significant numbers of northbound migrants).

In 1995, the first-ever (on Akimiski) intensive nest search during mid-incubation aimed at marking all nests in the inter-tidal and supra-tidal nesting areas. We found 654 active nests and 130 destroyed nests identified with confidence by down characteristics as snow goose (not Canada Goose, *Branta*

*See Documents Cited section.

canadensis) nests, for a minimum of 784 nest attempts in 1995. A repeat search of the western portion of the nesting area yielded 19 missed nests (i.e., unmarked) for every 100 active nests. Using this 19% to extrapolate, we estimated 778 active nests at the end of the second week of incubation. A similar extrapolation of the 130 destroyed nests yielded 155 destroyed nests (probably conservative because unattended nests are more easily missed than active nests; Walter and Rusch 1997) yielding an estimate of 933 nests in inter-tidal and supra-tidal areas in 1995. At the west end of the colony (53° 10-11′ N, 81° 30-35′ W), a graminoid fen south of a band of tall willows (*Salix* spp.) contained about 75 additional nests at low density; these were noted from the air, but the area was not intensively ground-searched. Thus, the total number of nesting pairs in 1995 was estimated at 1008.

In 1996, we found a total of 1682 active nests during mid-incubation and hatch and 135 depredated nests for a minimum 1817 nests. Included in the total were five isolated nests found in exhaustively searched Canada Goose nesting areas just west of Houston Point (53° 11′ N, 81° 08′ W). Some low-density nesting was also discovered on the inter-tidal and supra-tidal flats west of the limit of the main area searched (i.e., west of Lumsden River) as far as 53° 11′ N, 81° 41′ W and also inland from the tall willows (see 1995). These two areas added an estimated 100 nests. The total colony estimate for 1996 was therefore approximately 1917 pairs. This doubling of nests occurred without a major expansion of area occupied, so nest density increased, especially on higher ground around the Forked and Thompson rivers in the supra-tidal zone near the willow line.

In 1997, we found a total of 1583 active nests during mid-incubation and hatch plus 92 depredated nests for a minimum 1675 nests. Included in the total were 30 nests found east of the main 1995 and 1996 nesting areas (i.e., east of Stitt River). An estimated 50 additional nests were present in a low density nesting area inland from the tall willows at the west end of the colony. The total colony estimate for 1997 was therefore approximately 1725 pairs.

Productivity and Colour Composition

The proportion of young present in brood flocks varied between 34.3 and 75% from 1957-1997, but the exceptional high (1958) and some lows (1968, 1987-1990) may have been biased because of extremely low sample sizes (Table 1). Nevertheless, the long-term average was 54.4% young and there were no years of major reproductive failure. The proportion of blue-morph geese in photographs ranged from 74% to 92%, excluding two years when fewer than four families were recorded (1963, 1989) with a long-term average of 79.6% (Table 1). Compared with other eastern arctic colonies, this colour composition is most similar to the Bowman Bay, Baffin Island, colony (81% blue) but also is similar to the Cape Henrietta Maria, Ontario, colony (73% blue) (Kerbes 1975).

Migration and Wintering Areas

In total, 145 recoveries from Lesser Snow Geese banded in 1974-1992 were reported in 12 U.S. states and four Canadian provinces. Fifty recoveries (35%) were reported from James Bay (Akimiski Island and the coast of northern Ontario and Quebec). Other recovery locations (in descending order) were Louisiana (24), Texas (15), Iowa (9), North Dakota (6), South Dakota (6), Manitoba (5), Nebraska (5), Missouri (4), Arkansas (4), Michigan (1), Wisconsin (1), Minnesota (1), and Mexico (1). One female neck-banded more recently (1996) was recovered in Maryland, but these recoveries generally reflected a distribution similar to other eastern Lesser Snow Goose colonies (Francis and Cooke 1992).

Discussion

Smith (1944*) and Manning (1952) mentioned being told in the 1940s by the Cree that white- and blue-morph Snow Geese sometimes nested on Akimiski Island, but neither author was able to obtain any direct evidence. Similar Cree reports of small numbers of nesting white- and blue-morph geese at Cape Henrietta Maria were confirmed in 1947 (Hanson et al. 1972). It is thus probable that intermittent nesting occurred in suitable habitat on Akimiski Island for many years prior to the establishment phase we have documented, but there is no evidence of substantial nesting before the late 1960s.

The establishment of substantial goose nesting on Akimiski Island coincides with other rapid growth events in the Mid-Continent Population (Kerbes 1975; Abraham et al. 1996). Increases during the period 1968-1973 were documented at mainland southern Hudson Bay colonies at McConnell River, Northwest Territories (MacInnes and Kerbes 1987), La Perouse Bay, Manitoba (Cooke et al. 1995) and Cape Henrietta Maria, Ontario (Hanson et al. 1972).

Although female Snow Geese are generally strongly philopatric to the colony in which they were hatched (Cooke et al. 1975), exceptions have been documented. Geramita and Cooke (1982) documented a case of mass immigration at La Perouse Bay, Manitoba. MacInnes and Kerbes (1987) interpreted events at the McConnell River, Northwest Territories, colony as a case of immigration and consolidation of birds from nearby nesting areas and noted the probable attraction of established birds (a decoy effect). Johnson (1995) used mark-recapture methods to show a high rate of female immigration in the first six years at a small, newly established Alaskan colony followed by a low and relatively constant rate of 12% for a ten-year period.

Mechanisms for new colony establishment or extant colony growth vary and are not completely understood. Prolonged weather-induced delays in northward migration may facilitate lapses in female fidelity to more northerly natal colonies. Hanson et al. (1972) suggested this as a reason for "vagrant" non-colonial nesting and the southward expansion of nesting along the southern Hudson Bay coast, although they found no strong relationship with weather in a short series of years. Climatic conditions did, however, cause late spring thaws at northern colonies in 1968 and 1972, with correspondingly low reproduction (Boyd et al. 1982). Migration from James Bay, the major spring staging area for the Baffin Island colonies, was presumably correspondingly late in those years. Spring surveys in 1972 documented major and unprecedented numbers of staging Lesser Snow Geese on the north shore of Akimiski Island from the south-west tip to Houston Point (295 000 birds estimated on 18-19 May 1972; Curtis 1973*). It is noteworthy that the start of annual nesting on Akimiski was in 1968 and the first substantial spike in number of breeding pairs was in 1972. The colour proportions then, as now, were very similar to Bowman Bay, Baffin Island. This circumstantial evidence suggests that long-delayed Baffin Island staging birds remained to nest on Akimiski Island that year.

In 1969 and 1973 (i.e., the first year subsequent to each of the late years when higher than usual nesting occurred on Akimiski), the colony experienced even higher peaks in the number of nesting birds. Neither appears directly attributable to poor weather on northern colonies. Recruitment of first time nesters from previous local reproduction stimulated by the first late year (1968) and the 1969 effort may have contributed to the surges in 1972 and 1973 because birds hatched in those years would be expected to enter the breeding population in good numbers in 1972 and 1973 as 3- and 4-year-olds. This would be additive to any late-year immigration effect. After a core group of nesters was established, good average nesting conditions such as have been experienced on Akimiski Island would promote continued nesting. In addition, Johnson (1995) hypothesized that most females immigrate as juveniles, possibly as adoptees in intact families, and showed low female immigration rates to the Howe Island colony following years of reproductive failure there (i.e., years of few families with young to attract adoptees) consistent with that idea. Thus, good reproduction at a new colony would promote continuing immigration.

The late year immigration scenario may have played out again in other years at Akimiski, such as 1996, an extremely late year in the eastern arctic when Baffin Island colonies had only 10% of their 1995 breeding effort (F. D. Caswell, Canadian Wildlife Service, personal communication). The doubling of nests on Akimiski Island in 1996 is unrealistic for intrinsic growth alone, and seems best explained by a combination of new recruits from the island and substantial displaced birds from Baffin Island and/or Cape Henrietta Maria. The similarity of number of pairs in 1997 (not a particularly late year) suggested that those immigrants established an affinity for Akimiski and they may therefore have been mostly first-time nesters in 1996. Fidelity to the first nest site is strong, even when the first nest is located in an area distant from the bird's other prebreeding experience (Abraham 1980; Cooke and Abraham 1980). Continued monitoring of will help determine whether the 1996 surge was another in a series of population-climate interactions that contributed to the growth of this colony.

The Akimiski Island Lesser Snow Goose colony is the southernmost substantial nesting location in the world, although isolated pairs have successfully nested farther south in James Bay (McRae et al. 1994). It is also the only persistent nesting colony in James Bay. The absence of nesting failures on Akimiski Island is consistent with its southerly position in the species distribution and the relatively mild climate compared with northern latitudes. Its more than three-fold increase over the past 20 years matches that of the mid-winter index of Mid-Continent Population Snow Geese. Although it is presently small, continued expansion should be expected given events of the past three decades and our knowledge of the mechanisms of colony growth. The colony should also be monitored because its expansion has implications for other species sharing its range. The colony overlaps that portion of the range of the Southern James Bay Canada Goose Population with the highest nesting density (Leafloor et al. 1996; *in press*). This population declined in the 1980s, and competition with Snow Geese for resources is a prime concern for population managers.

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Documents Cited (marked * in text)

Boyer, G. F., H. G. Lumsden, and **H. C. Hanson.** 1958. Aerial waterfowl surveys — James Bay-Hudson Bay coastal plain of Ontario and Akimiski Island, N.W.T. Canadian Wildlife Service Internal Report. 13 pages.

Curtis, S. G. 1973. The movement of geese through James Bay, Spring 1972 — A Preliminary Report. Canadian Wildlife Service Report, James Bay Series Number 10. 31 pages.

Smith, R. H. 1944. An investigation of the waterfowl resources of the west coast of James Bay 1944. Unpublished report. U.S. Fish and Wildlife Service. 80 pages.

Literature Cited

Abraham, K. F. 1980. Breeding site selection of Lesser Snow Geese. Ph.D. thesis. Queen's University, Kingston, Ontario. 148 pages.

Abraham, K. F., R. L. Jefferies, R. F. Rockwell, and **C. D. MacInnes.** 1996. Why are there so many white geese in North America? Pages 79–92 *in* Proceedings of the 7th International Waterfowl Symposium, February 4-6, 1996. *Edited by* J. Ratti, Ducks Unlimited Inc., Memphis, Tennessee.

Alisauskas, R., and **H. Boyd.** 1994. Previously unrecorded colonies of Ross' and Lesser Snow Geese in the Queen Maud Gulf bird sanctuary. Arctic 47: 69–73.

Boyd, H., G. E. J. Smith, and **F. G. Cooch.** 1982. The Lesser Snow Geese of the eastern Canadian Arctic: their status during 1964-1979 and their management from 1982 to 1990. Canadian Wildlife Service Occasional Paper Number 46. 21 pages.

Cooke, F., and **K. F. Abraham.** 1980. Habitat and locality selection in Lesser Snow Geese: the role of previous experience. Proceedings of the International Ornithological Congress 17: 998–1004.

Cooke, F., C. D. MacInnes, and **J. P. Prevett.** 1975. Gene flow between breeding populations of Lesser Snow Geese. Auk 92: 493–510.

Cooke, F., R. F. Rockwell, and **D. Lank.** 1995. The Snow Geese of La Perouse Bay. Oxford University Press, New York, New York. 297 pages.

Francis, C. M., and **F. Cooke.** 1992. Migration routes and recovery rates of Lesser Snow Geese from southwestern Hudson Bay. Journal of Wildlife Management 56: 279–286.

Geramita, J. M., and **F. Cooke.** 1982. Evidence that fidelity to natal breeding colony is not absolute in female Snow Geese. Canadian Journal of Zoology 60: 2051–2056.

Hanson, H. C., H. G. Lumsden, J. J. Lynch, and **H. W. Norton.** 1972. Population characteristics of three mainland colonies of Blue and Lesser Snow Geese nesting in the southern Hudson Bay region. Ontario Ministry of Natural Resources Research Report (Wildlife) Number 92. 38 pages.

Johnson, S. R. 1995. Immigration in a small population of Snow Geese. Auk 112: 731–736.

Kerbes, R. H. 1975. The nesting population of Lesser Snow Geese in the eastern Canadian Arctic: a photographic inventory of June 1973. Canadian Wildlife Service Report Series Number 35. 46 pages.

Kerbes, R. H. 1994. Colonies and numbers of Ross' geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary. Canadian Wildlife Service Occasional Paper Number 81. 45 pages.

Leafloor, J. O., K. F. Abraham, D. H. Rusch, R. K. Ross, and **M. R. J. Hill.** 1996. Status of Southern James Bay Population of Canada Geese. Pages 103–108 *in* Proceedings of the 7th International Waterfowl Symposium, February 4-6, 1996. *Edited by* J. Ratti, Ducks Unlimited Inc., Memphis, Tennessee.

Leafloor, J. O., M. R. J. Hill, D. H. Rusch, K. F. Abraham, and **R. K. Ross.** *In press.* Nesting ecology and gosling survival of Canada geese on Akimiski Island, Northwest Territories. *In* Canadian Wildlife Service Occasional Paper. *Edited by* K. Dickson. Ottawa, Ontario.

MacInnes, C. D., and **R. H. Kerbes.** 1987. Growth of the Snow Goose *Chen caerulescens*, colony at McConnell River, Northwest Territories: 1940–1980. Canadian Field-Naturalist 101: 33–39.

Manning, T. H. 1952. Birds of the west James Bay and southern Hudson Bay coasts. National Museum of Canada Bulletin Number 125 (Biological Series Number 43). 114 pages.

McRae, D., R. Stitt, and **N. C. Wilson.** 1994. A southern breeding range extension of the Lesser Snow Goose, *Chen caerulescens caerulescens*, James Bay, Ontario. Canadian Field-Naturalist 108: 223.

Thomas, V. G., and **J. P. Prevett.** 1982. The roles of the James and Hudson Bay Lowland in the annual cycle of geese. Le Naturaliste canadien 109: 913–925.

Walter, S. E., and **D. H. Rusch.** 1997. Visibility bias on counts of nesting Canada geese. Journal of Wildlife Management 61: 768–772.

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Activity Patterns and Daily Movements of the Eastern Coyote, *Canis latrans*, in Nova Scotia

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We studied the daily activity patterns and movements of 36 radio-collared Coyotes (*Canis latrans*) in Nova Scotia from January 1993 through August 1996. Coyotes exhibited several periods of activity and rest throughout the day. Mean length of active and rest periods were 136 ± 93 (± SD), and 164 ± 131 min, respectively. The mean duration of active and rest periods were not significantly different with respect to time of day, season, or Coyote reproductive status. Annually, Coyotes traveled an average of 20.2 ± 8.9 km per 24-hour period with the greatest distances being traveled by breeding males during the pup rearing season (24.9 ± 9.2 km) and the least by all Coyotes (pooled) during winter (14.3 ± 5.9 km).

Key Words: Eastern Coyote, *Canis latrans*, activity patterns, movements, Nova Scotia.

Activity patterns represent a fundamental aspect of animal behavior (Aschoff 1964; Enright 1970; Nielsen 1983). Although by definition activity includes all movement, foraging, grooming, etc., most research is primarily concerned with foraging. Predators should be able to maximize fitness by timing activity to coincide with that of major prey species (Zielinski et al. 1983; Lorvari et al. 1994). However, factors such as social and physiological constraints (Chappell 1980), environmental conditions (Aschoff 1964), and predation risk (Sih 1987) often lead to a trade-off in the evolution of activity patterns. These factors may not only determine the timing of activity, but how an animal behaves once active (Loughry 1993; McDonough and Loughry 1997).

The Eastern Coyote (*Canis latrans*) is a recent immigrant to northeastern North America (Moore and Parker 1992). Most studies of Coyote activity have been conducted within the species' historic range, have focused on movements (Andelt and Gipson 1979; Smith et al. 1981; Holzman et al. 1992) and concluded that Coyotes are largely nocturnal. In addition, Shivik and Crabtree (1995), and Shivik et al. (1997) used motion sensitive radio-collars to study Coyote activity in California and reported little difference in Coyote activity with respect to time of day. None of the aforementioned studies detected a difference in activity with respect to sex, while most agree that Coyote activity varies seasonally, with relatively less activity during winter (Bekoff and Wells 1981; Laundré and Keller 1981; Shivik and Crabtree 1995; Shivik et al. 1997).

Relative to their historic range, Coyotes in the forested regions of northeastern North America appear to be more active during the day (Major and Sherburne 1987; Morton 1988). However, activity patterns of Eastern Coyotes remain poorly described. Throughout much of the Northeast, Coyotes must contend with decreased prey availability and diversity in comparison with their historic range (Harrison 1992; Patterson et al. 1998). This reduction in prey abundance has resulted in significantly larger home range sizes among Eastern Coyotes (Messier and Barrette 1982; Brundige 1993; Harrison 1992; Major and Sherburne 1987), but the effects on daily movements and activity remain unknown. Harrison and Gilbert (1985) studied the relative movements of adult Coyotes attending pups in Maine but provided little information on daily distances traveled and activity patterns.

Recently, the Eastern Coyote has been identified as a major limiting factor of White-tailed Deer (*Odocoileus virginianus*) populations throughout the Northeast (Lavigne 1992; Patterson 1994; Parker 1995; Crête and Lemieux 1996). Pekins (1992) and Brundige (1993) estimated deer consumption rates of Eastern Coyotes based on energy requirements and diet. Pekins (1992) reviewed the winter bioenergetics of Eastern Coyotes and cited the lack of data concerning movements and activity budgets as a major limitation to modeling consumption rates.

The specific objectives of the present study were to: (1) determine the daily distances traveled by Coyotes living in a northeastern forested environment during both summer and winter by sex, reproductive status and season; (2) describe Coyote activity patterns in relation to season and reproductive status; and (3) determine the mean length and interspersion of activity and resting bouts.

Study Areas

The study was conducted from January 1993 through August 1996 in two geographic areas of Nova Scotia as part of an intensive study of Coyote ecology and predation on White-Tailed Deer (Patterson et al. 1998). The Queens County (QC) study area was situated in central southwestern Nova Scotia (44° 20′ N, 65° 15′ W) and included the eastern half of Kejimkujik National Park (~200 km^2) and approximately 300 km^2 of managed land (primarily forested) directly to the east of the Park. The area included a diversity of forest stands. This area does not generally receive accumulations of snow in winter >20 cm, and therefore local deer do not aggregate in yards during winter (Lock 1997; MacDonald 1996). The second area, the Cape Breton (CB) Study Area, was situated on Cape Breton Island (45° 45′N, 61° 15′ W) and was centered on the 24-km^2 Eden deer wintering area which typically contains ~200 deer from January through March (Patterson et al. 1998). Both the amount and duration of snow-cover was greater in the CB study area. Patterson et al. (1998) provide more detailed information on the study areas.

Methods

Coyotes were captured using #1.75 and #3 coil-spring foot hold traps and physically restrained with a snare pole. They were immobilized with an intramuscular injection of ketamine HCL (Rogarsetic, Rogar/STB, Inc., London, Ontario) or Telazol® (A. H. Robins, Richmond, Virginia) at dosages of 15 and 10 mg/kg respectively, of estimated body mass). Coyotes were classified as being either juvenile (<1 year of age), yearling, or adult based on tooth development and appearance (Parks 1979). Each Coyote was equipped with a radio collar (Holohil Systems Ltd., Woodlawn, Ontario, and Lotek Engineering Inc., Newmarket, Ontario) weighing approximately 250 g .

We monitored activity and movements of 36 Coyotes during the study. Coyotes were monitored during intensive monitoring sessions and were also relocated opportunistically. The mean duration of intensive sessions was 15.2 ± 7.2 hours (n = 60). Intensive monitoring sessions were generally conducted once/week from May- August and < once/month during the rest of the year. We classified Coyotes as breeding residents, resident associates, juveniles, and transients (Messier and Barrette 1982; Person and Hirth 1991). Breeding residents were adult animals that had established home ranges and exhibited breeding behavior (e.g., denning, pair bonding, or lactation). Resident associates were adults with home ranges that overlapped extensively with those of resident breeders and were observed, or suspected, of interacting with breeding residents, based on tracks and relocations. Offspring of the year were classified as juveniles. Transient Coyotes were solitary adults with large and poorly defined home ranges. Due to sample size constraints, we retained only the classifications of breeding males, breeding females, and non-breeding adults (>1 yr) for purposes of comparison.

We relocated Coyotes using standard methods of ground based triangulation with hand-held Yagi antennas (White and Garrott 1990). Coyote activity was assessed based on evidence of movements or changes in signal modulation at the time of relocation (Major and Sherburne 1987; Person and Hirth 1991; Drew and Bissonette 1997). Signal modulation was assessed by placing the antennae in a stationary position and listening for fluctuations in signal strength or pitch over a period of 30 seconds. We recorded activity as moving, resting, or unknown.

Although signal modulation may be a poor method of activity determination for animals with relatively subtle actively (White and Garrott 1990), we believe this method was useful for determining activity of Coyotes. Shivik et al. (1997) commented that even subtle movements by bedded (inactive) Coyotes could trip the activity switches of motion sensitive collars and thus lead to an overestimation of activity. While snow tracking, we frequently used radio-telemetry to locate the tracks of collared Coyotes. Whenever we approached bedded Coyotes (later confirmed by tracks in the snow) signal modulation was constant until the Coyotes were spooked from their beds. At that time the signal always became extremely variable. This was readily detectable even when the signal was very strong. Given the blatantly variable signal received from the collar of a moving Coyote, we believe that we rarely failed to detect activity in Coyotes. However, factors other than movement may result in a variable signal (White and Garrott 1990), thus our estimates of activity should be viewed as maximal.

Based on field tests involving locating collars at fixed locations from known stations, bearing error was estimated to be <4°. Triangulation data were converted to point locations using the Maximum Likelihood Estimator computed by the software program LOCATE II (Nams 1990). We rejected triangulation fixes with error ellipses exceeding 0.5 km^2. The remaining fixes had an average confidence ellipse of 0.097 ± 0.11 km^2 ($\bar{x}$ ± SD; n = 2088).

Daily activity patterns were determined by pooling the total number of observations of Coyotes for each of the following time periods: early morning — one hour before sunrise to two hours after sunrise; late morning — two hours after sunrise until 12:30; afternoon — 12:30 until one hour before sunset; early evening — one hour before sunset until two hours after sunset; night — two hours after sunset until one hour before sunrise of the following morning. The actual time of sunrise and sunset was averaged for each season. Because this analysis assumed that each observation be statistically independent with regard to activity, we used only those values obtained from relocations separated by >4.5 hours (Harrison and Gilbert 1985). Data were analyzed in relation to the following biological seasons (Harrison and Gilbert 1985; Smith et al. 1981): pair formation and breeding, 1 December - 31 March; pup-rearing, 1 May - 31 July; pup independence, 1 August - 15 September; dispersal, 16 September- 30 November. The relative frequencies of active and inactive observations among each time period were compared for each season using the chi-square distribution.

Coyote movements were estimated by summing the total distance traveled between successive locations separated by intervals ranging from 10 to 90 minutes and collected during sessions >6 hours. Estimates of daily distances traveled were extrapolated from the total distance traveled during each session. Duration of activity and rest periods were recorded to the nearest 5 min from the continuous-monitoring data. Only complete active or rest periods (ones for which we documented both the onset and cessation) were retained for analysis. This resulted in the censoring of 80 out of 315 sessions (25.4%). We were concerned that this may have introduced a systematic bias if proportionally more "long" periods were censored. However, the mean length of censored periods was significantly less than that of complete periods (Mann-Whitney $U_{80, 235} = 6980.5$, $P = 0.0006$).

We compared daily distances traveled, and the mean duration of both activity and resting periods using a one-way analysis of variance (ANOVA) with time of day (dusk — dawn vs. day), season, and Coyote reproductive status (males tending pups, females tending pups, and non-breeding Coyotes) as explicative variables. Significant differences were determined using the Student-Newman-Keuls test. In cases where the hypothesis of homogeneity of variances among mean ratios was rejected, mean rank-values were compared using a Kruskal-Wallis test (Zar 1996: 198-202).

Results

Daily and seasonal activity patterns

Based on signal modulation, Coyotes were recorded as being either active or resting on 1400 occasions ($\bar{x}$ = 39 ± 8 (SE) relocations per Coyote, range = 2 – 171) during all seasons, and hours of the day (Table 1, Figure 1). Overall, Coyotes were active during 51% of these observations, suggesting that Coyotes spend approximately equal time resting and active. Coyotes exhibited a multi-modal pattern of activity, with several periods of rest and activity throughout the day and night. However, they were generally most active at dusk and least active during late morning (Table 1, Figure 1). Seasonally, Coyotes were active 44.6–58.2% of the time (Table 1). Seasonal differences in activity were marginally significant ($\chi^2 = 7.3$, d.f. = 3, $P = 0.07$, Table 1), suggesting Coyotes spend relatively less time active during winter.

The mean length of rest and activity periods was 164 ± 131 (n = 118), and 136 ± 93 (n = 117) min, respectively (Table 2). Thus Coyotes examined in this study had a total of approximately 10 resting and active periods each day. The mean durations of active and resting periods were not significantly different (Mann-Whitney $U_{117, 118} = 6351$, $P = 0.29$), nor were there any significant differences in the duration of active or resting periods in relation to time of day, season, or Coyote reproductive status ($H = 14.2$, $d.f. = 15$, $P = 0.51$; Table 2).

Daily Movement Distance

Annually, Coyotes traveled an average of 20.2 ± 8.9 km (n = 60) per 24-hour period (Table 3). The greatest distances traveled were by breeding males during the pup rearing season (24.9 ± 9.2 km, n = 21). The mean daily distance traveled by breeding males during the pup rearing season was significantly greater than that traveled by breeding females during the same period (14.6 ± 6.3 km, Kruskal-Wallis $Q = 4.1$, $P < 0.05$), all Coyotes during winter (14.3 ± 5.9 km, $n = 8$, $Q = 4.4$, $P < 0.05$), and non breeding Coyotes during summer (19.8 ± 8.2 km, $Q = 3.0$, $P < 0.05$, Table 3). There were no other significant differences among daily distances traveled.

Discussion

In this study, Coyotes exhibited multiple active and resting periods per day. Conversely, throughout their historic range, Coyotes are largely nocturnal resulting in uni-modal activity patterns (Andelt and Gipson 1979; Laundré and Keller 1981; Smith et al. 1981; Holzman et al. 1992; Shivik and Crabtree 1995). Studies conducted in other forested regions of northeastern North America (Major and Sherburne 1987; Morton 1988; Brundige 1993) support our findings that Eastern Coyotes are active throughout the day and night. Most of the studies conducted in the historic range of Coyotes were conducted in either areas of intensive agriculture or other human development. We believe that the increased availability of cover in much of northeastern North America may facilitate daytime movements. Shivik et al. (1997) determined that Coyotes were generally active throughout the day in a mountainous region of the Sierra Nevada, California.

Shivik and Crabtree (1995) suggested that seasonal temperatures were the primary cause of changes in daily activity patterns (a switch from primarily nocturnal activity to activity throughout the day with decreasing temperatures) of Coyotes. It has also been suggested that nocturnal activity by Coyotes may be prompted by high levels of human

TABLE 1. Daily activity (calculated as the percent of independent locations for which Coyotes were active) for 36 radio-collared Coyotes in Nova Scotia, January 1993–August 1996. Data from all Coyotes >6 months old were pooled regardless of social status.

Season	Time period	Hours	Percent total time active	Number of locations	X^2
Pair formation and breeding	Early morning	0601 – 0900	50.0	30	
	Late morning	0901 – 1230	34.6	188	
	Afternoon	1231 – 1600	44.5	128	
	Early evening	1601 – 1900	66.1	62	
	Night	1901 – 0600	53.3	45	
			44.6	453	11.7***
Pup rearing	Early morning	0401 – 0700	47.1	34	
	Late morning	0701 – 1200	50.5	111	
	Afternoon	1201 – 1930	47.6	164	
	Early evening	1931 – 2230	81.7	60	
	Night	2231 – 0400	53.1	49	
			53.8	418	10.4**
Pup independence	Early morning	0501 – 0800	53.1	32	
	Late morning	0801 – 1230	31.3	48	
	Afternoon	1231 – 1830	47.7	88	
	Early evening	1831 – 2130	77.1	35	
	Night	2131 – 0500	51.2	41	
			50.0	244	8.7*
Dispersal	Early morning	0531 – 0830	70.0	10	
	Late morning	0831 – 1200	41.5	82	
	Afternoon	1201 – 1600	58.8	97	
	Early evening	1601 – 1900	75.4	65	
	Night	1901 – 0530	61.3	31	
			58.2	285	7.5
Total			51.1	1400	7.3*

*$P < 0.10$, **$P < 0.05$, ***$P < 0.02$; Expected values for Chi square analysis assume equal activity throughout the day or among seasons.

activity (Gese et al. 1989) and/ or exploitation (primarily hunting, Andelt 1985). Although trapping of Coyotes is common in Nova Scotia (Sabean 1993), Coyotes are hunted very little and are probably less disturbed than in many areas of their historic range. We suspect that activity throughout the day is typical of undisturbed Coyote populations, particularly in areas providing abundant cover.

Our estimates of daily distances traveled (20.2 km/ 24 hr) were greater than those reported for Coyotes in Nebraska (10.9 km, Andelt and Gipson 1979), Oklahoma (6.2 km, Litviatis and Shaw 1980), and Texas (8 km, Andelt 1985), but similar to those reported for Eastern Coyotes in the Adirondack mountains of New York (24.4 km, Brundige 1993). The larger daily distances traveled by Coyotes in the forested regions of the Northeast are likely due to reduced prey availability as suggested by Harrison (1992) and Person and Hirth (1991) for differences in home range sizes. Regardless of prey density, the maintenance of larger territories by Coyotes in the Northeast would require greater movements. Researchers calculating the energetic costs of Eastern Coyotes using movement data collected from Coyotes in their historic range would underestimate these costs considerably.

The greatest daily distances traveled by Coyotes in this study were by breeding males during the pup-rearing season. Harrison and Gilbert (1985) reported that, although both parents provide for the pups, females are generally more restricted to the den site. Thus, increased movements exhibited by breeding males probably relate to the demands of providing for their mate and pups. Daily distances traveled by breeding adult males in Idaho were also greatest during pup rearing season (Laundré and Keller 1984).

Daily distances traveled by Coyotes during the pair formation/ breeding season (winter) were shorter than all other times of the year. Several studies (Ozaga and Harger 1966; Andelt and Gipson 1979; Parker and Maxwell 1989) have reported increased Coyote mobility during the breeding season and sug-

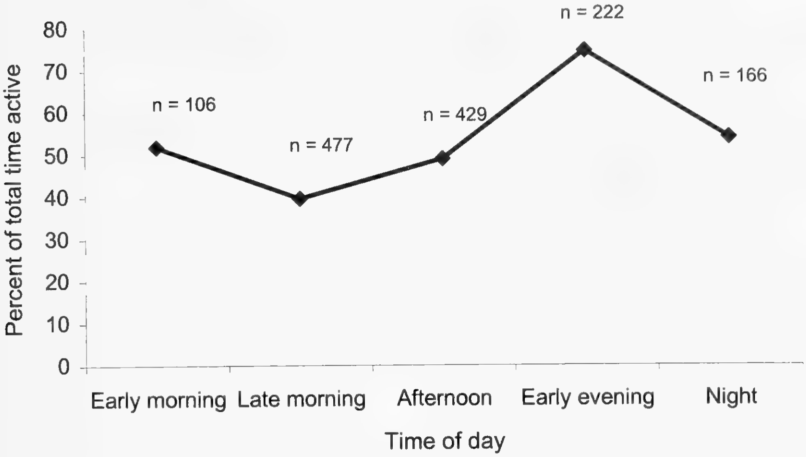

FIGURE 1. Daily activity of 36 radio-controlled Coyotes in Nova Scotia, January 1993–August 1996. Time periods were as follows: early morning — one hour before sunrise to two hours after sunrise; late morning — two hours after sunrise until 12:30; afternoon — 12:30 until one hour before sunset; early evening — one hour before sunset until two hours after sunset; night — two hours after sunset until one hour before sunrise of the following morning.

gested mate seeking by unpaired Coyotes, and an overall increase in territoriality at this time of year, were the principal causes. Breeding pairs of Coyotes monitored during this study were almost always together (the exception being during the pup rearing season), and were quickly replaced when killed or injured (B. R. Patterson, unpublished data). Thus, mate seeking was probably not a significant influence on movements during this study. Given the large territory sizes typical of Eastern Coyotes (Harrison 1992), we should have observed a considerable increase in activity and movements during the pair formation and breeding period if increased territoriality influenced movements; however, this was not the case. Gese et al. (1996) reported that Coyotes spent progressively more time resting as snow depth and large mammal carcass biomass increased in Yellowstone National Park, Wyoming. Coyotes in the Sierra Nevada, California, exhibited decreased activity in winter despite the absence of ungulate carcasses (Shivik et al. 1997). Shivik et al. (1997) felt that this reduction in activity allowed Coyotes to remain in an area with a seasonally reduced prey base and harsh weather conditions. However, Pekins (1992) reported that winter thermoregulatory costs for Coyotes in northeastern North America are likely minimal. We suggest that decreased movements during this season were related to increased vulnerability of White-tailed Deer and Snowshoe Hare (*Lepus americanus*) (Patterson et al. 1998).

Coyotes monitored during this study showed increased levels of activity during crepuscular peri-

TABLE 2. Mean duration (min) of activity and resting periods for 16 adult (>1 yr.) Coyotes in Nova Scotia, January 1993 – August 1996. Seasons were defined as, pair formation and breeding, December – March; pup rearing, May – July; pup independence, August - 15 September; dispersal, 16 September – November. The number of Coyotes assigned to each social status during each season is given in parenthesis. The number of periods measured for each category is given as n.

Coyote social status	Season	Rest periods ($\bar{x} \pm$ SD)	n	Activity periods ($\bar{x} \pm$ SD)	n
Breeding males (6)	Pup rearing	165 ± 109	46	129 ± 84	50
Breeding females (3)	Pup rearing	146 ± 112	12	115 ± 85	12
Non-breeding adults (10)	July–September	163 ± 154	45	149 ± 113	39
All adults (5)	Pair formation and breeding	177 ± 36	15	137 ± 75	16
Pooled (16)		164 ± 131	118	136 ± 93	117

TABLE 3. Mean daily distances (km) traveled during pup rearing (May – July), summer (June – September), and pair formation and breeding (December – March) for 16 adult (>1 yr.) Coyotes in Nova Scotia, January 1993 – August 1996.

Season	Coyote social status	Number of Coyotes	Number of monitoring sessions	Duration ($\bar{x}$± SD)	Distance traveled/ 24 h ($\bar{x}$± SD)	Total No. locations
Pup Rearing	Breeding males	6	21	14.9 ± 6.5	24.8 ± 9.2	535
Pup Rearing	Breeding females	3	7	15.9 ± 6.1	14.6 ± 6.3	148
Summer	Non-breeding adults	10	24	12.7 ± 7.0	19.8 ± 8.2	553
Pair formation and breeding	All adults	5	8[a]	23.1 ± 4.5	14.3 ± 5.9	182
			60	15.2 ± 7.2	20.2 ± 8.9	1418

[a]Includes two sessions (13-14 February 1995, and 2-3 March 1995) where the total distance traveled by radio-collared Coyotes in 24 hours was measured by snow- tracking. Mean distance determined by snow-tracking (16.2 ± 0.29 km) was not significantly different than the mean distance determined with telemetry (13.7 ± 6.8 km, t = 0.48, d.f. = 6, P = 0.65)

ods. Increased activity levels near daybreak and dusk correspond roughly with the activity patterns shown by snowshoe hare and white-tailed deer (Mech et al. 1966; Heezen and Tester 1967; Morton 1988). Thus, these periods of Coyote activity may be related to hunting. However, Brundige (1993) reported that Coyotes in the Adirondack Mountains of New York hunted for deer during midday in winter. He felt that Coyotes purposely chose this time of day to hunt because surprising deer in their beds conferred an advantage relative to hunting deer that were active. Further research is needed to clarify the relationship between Coyote activity patterns and foraging ecology. However, we agree with Laundré and Keller (1981) and Morton (1988), that the activity patterns of prey species likely have a major influence on the timing of Coyote activity.

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Literature Cited

Andelt, W. F. 1985. Behavioral ecology of Coyotes in south Texas. Wildlife Monographs 90. 45 pages.

Andelt, W. F., and **P. S. Gipson.** 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management 43: 944–951.

Aschoff, J. 1964. Survival value of diurnal rhythms. Symposia of the Zoological Society of London 13: 79–98.

Bekoff, M., and **M. C. Wells.** 1981. Behavioral budgeting by wild coyotes: the influence of food resources and social organization. Animal Behavior 29: 794–801.

Brundige, G. C. 1993. Predation ecology of the eastern coyote (*Canis latrans var.*) in the Adirondacks, New York. Ph.D. dissertation, State University of New York, College of Environmental Science and Forestry. Syracuse. 196 pages.

Chappell, M. A. 1980. Thermal energetics and thermoregulatory costs of small arctic animals. Journal of Mammalogy 61: 278–291.

Crête, M., and **R. Lemieux.** 1996. Population dynamics of coyotes colonizing the boreal forest of southeastern Québec. Journal of Wildlife Research 1: 99–105.

Drew, G. S., and **J. A. Bissonette.** 1997. Winter activity patterns of American martens (*Martes americana*): rejection of the hypothesis of thermal-cost minimization. Canadian Journal of Zoology 75: 812–816.

Enright, J. T. 1970. Ecological aspects of endogenous rhythmicity. Annual Review of Ecology and Systematics 1: 221–238.

Gese, E. M., R. L., Ruff, and **R. L. Crabtree.** 1996. Foraging ecology of coyotes (*Canis latrans*): the influence of extrinsic factors and a dominance hierarchy. Canadian Journal of Zoology 74: 769–783.

Gese, E. M., O. J. Rongstad, and **W. R. Mytton.** 1989. Changes in coyote movements due to military activity. Journal of Wildlife Management 53: 334–339.

Harrison, D. J. 1992. Social ecology of coyotes in northeastern North America: Relationships to dispersal, food resources, and human exploitation. Pages 53–72 *in* Ecology and management of the Eastern Coyote. *Edited by* A. H. Boer, Wildlife Research Unit, University of New Brunswick, Fredericton. 194 pages.

Harrison, D. J., and **J. R. Gilbert.** 1985. Denning ecology and movements of coyotes in Maine during pup rearing. Journal of Mammalogy 66: 712–719.

Heezen, K. L., and **J. R. Tester.** 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. Journal of Wildlife Management 31: 124–140.

Holzman, S., M. J. Conroy, and **J. Pickering.** 1992.

Home range, movements, and habitat use of coyotes in south-central Georgia. Journal of Wildlife Management 56: 139–146.

Lavigne, G. R. 1992. Sex/age composition and physical condition of deer killed by coyotes during winter in Maine. Pages 141–159 *in* Ecology and management of the Eastern Coyote, *Edited by* A. H. Boer, Wildlife Research Unit, University of New Brunswick, Fredericton. 194 pages.

Laundré, J. W., and **B. L. Keller.** 1981. Home range use by coyotes in Idaho. Animal Behavior 29: 449–461.

Laundré, J. W., and **B. L. Keller.** 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management 48: 127–139.

Litviatis, J. A., and **J. H. Shaw.** 1980. Coyote movements, habitat use, and food habits in southwestern Oklahoma. Journal of Wildlife Management 44: 62–68.

Lock, B. A. 1997. Deer wintering habitat models for two regions of Nova Scotia. M.S. thesis, Acadia University, Wolfville, Nova Scotia. 120 pages.

Lovari, S., P. Valier, and **M. Ricci Lucchi.** 1994. Ranging behavior and activity of red foxes (*Vulpes vulpes: Mammalia*) in relation to environmental variables, in a Mediterranean mixed pinewood. Journal of Zoology (London) 232: 323–339.

Loughry, W. J. 1993. Determinants of time allocation by adult and yearling black-tailed prairie dogs. Behavior 124: 23–43.

MacDonald, B. A. 1996. Spatial distribution, survivorship and effects of forest harvesting on over wintering white-tailed deer in Nova Scotia. M.S. thesis, Acadia University, Wolfville, Nova Scotia. 119 pages.

Major, J. T., and **J. A. Sherburne.** 1987. Interspecific relationships of coyotes, red foxes, and bobcats in western Maine. Journal of Wildlife Management 51: 606–616.

McDonough, C. M., and **W. J. Loughry.** 1997. Influences on activity patterns in a population of nine-banded armadillos. Journal of Mammalogy 78: 932–941.

Mech, L. D., K. L., Heezen, and **D. B. Sniff.** 1966. Onset and cessation of activity in cottontail rabbits and snowshoe hares in relation to sunset and sunrise. Animal Behavior 14: 410–413.

Messier, F., and **C. Barrette.** 1982. The social system of the coyote (*Canis latrans*) in a forested habitat. Canadian Journal of Zoology 60: 1743–1753.

Moore, G. C., and **G. R. Parker.** 1992. Colonization by the Eastern Coyote (*Canis latrans*). Pages 23–37 *in* Ecology and management of the Eastern Coyote, *Edited by* A. H. Boer, Wildlife Research Unit, University of New Brunswick, Fredericton. 194 pages.

Morton, L. D. 1988. Winter ecology of the Eastern Coyote (*Canis latrans*) in Fundy National Park. M.S. thesis, University of New Brunswick, Fredericton. 72 pages.

Nams, V. O. 1990. Locate II user's guide. Pacer computer software, Truro, Nova Scotia.

Nielsen, E. T. 1983. Relation of behavioral activity rhythms to the changes of day and night: a revision of views. Behaviour 89: 147–173.

Ozaga, J. J., and **E. M. Harger.** 1966. Winter activities and feeding habits of northern Michigan coyotes. Journal of Wildlife Management 30: 809–818.

Parker, G. R. 1995. Eastern Coyote: The Story of its Success. Nimbus Publishing Ltd., Halifax, Nova Scotia. 256 pages.

Parker, G. R., and **J. W. Maxwell.** 1989. Seasonal movements and winter ecology of the coyote, *Canis latrans*, in northern New Brunswick. Canadian Field-Naturalist 103: 1-11.

Parks, M. B. 1979. Physical and behavioral development of captive eastern coyote pups. M.S. thesis, University of Maine, Orono. 60 pages.

Patterson, B. R. 1994. Surplus killing of White-tailed Deer, *Odocoileus virginianus*, by Coyotes, *Canis latrans*, in Nova Scotia. Canadian Field-Naturalist 109: 484–487.

Patterson, B. R., L. K. Benjamin, and **F. Messier.** 1998. Prey switching and the feeding habits of the eastern coyote in relation to white-tailed deer and snowshoe hare densities. Canadian Journal of Zoology 76.

Pekins, P. J. 1992. Winter diet and bioenergetics of eastern coyotes: a review. Pages 87–99 *in* Ecology and management of the Eastern Coyote. *Edited by* A. H. Boer, Wildlife Research Unit, University of New Brunswick, Fredericton, New Brunswick. 194 pages.

Person, D. K., and **D. H. Hirth.** 1991. Home range and habitat use of coyotes in a farm region of Vermont. Journal of Wildlife Management 55: 443–441.

Sabean, B. 1993. Furbearer report. Nova Scotia Trappers Newsletter 29: 3–7.

Shivik, J. A., and **R. L. Crabtree.** 1995. Coyote activity levels in relation to presence of California Gulls at Mono Lake, California. California Fish and Game 81: 22–28.

Shivik, J. A., M. M. Jaeger, and **R. H. Barrett.** 1997. Coyote activity patterns in the Sierra Nevada. Great Basin Naturalist 57: 355–358.

Sih, A. 1987. Predators and prey lifestyles: an evolutionary overview. Pages 203–224 *in* Predation: direct and indirect impacts on aquatic communities, *Edited by* W. C. Kerfoot, and A. Sih, University Press of New England, Hanover, New Hampshire.

Smith, G. J, J. R., Cary, and **O. J. Rongstad.** 1981. Sampling strategies for radio-tracking coyotes. Wildlife Society Bulletin 9: 88–93.

White, G. C., and **R. A. Garrott.** 1990. The analysis of wildlife radio-tracking data. Academic Press, Inc. New York. 383 pages.

Zar, J. H. 1996. Biostatistical Analysis. 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 662 pages.

Zielinski, W. J., W. D. Spencer, and **R. H. Barrett.** 1983. Relationship between food habits and activity patterns of pine martens. Journal of Mammalogy 64: 387–396.

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Habitat Use by Bats, *Myotis* spp., in Western Newfoundland

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Bat diversity and activity patterns were monitored using mist-nets and bat detectors, and roosting habitat was investigated using radio-telemetry in western Newfoundland during June-August 1995. Of the three species of bat known to occur in Newfoundland (*Lasiurus cinereus*, *Myotis lucifugus*, and *M. septentrionalis*), only the latter two were detected or captured. Myotis bats were recorded with detectors at 87% of the riparian sample sites, although at relatively low levels (mean of 19.4 commuting passes/hr). These detector results suggest that myotis bats are ubiquitous, yet not very abundant in western Newfoundland. Most captures were of *M. lucifugus* (66%, n = 30), yet *M. septentrionalis* appear to be more common than previously thought, representing 34% (n = 15) of the captures. Myotis bats roosted in holes (n = 4), in cracks (n = 2), and under loose bark (n = 2) of standing dead trees, generally close to cutblock edges and sources of water (presumably foraging sites). Compared to those trees available (based on random transects in cutblocks and forests), bats did not appear to select roost trees based on many of the characteristics I measured (% bark remaining, diameter at breast height, stand slope, or species group (deciduous or conifer)). However, bats tended to select roost trees of smaller height classes (0-5 and 11-15 m) and with greater numbers of cavities than those available. Because most roosts were located along edge habitat, forest harvesting may increase accessibility to roosts for some bats by creating corridors and openings through the forest. However, it is still unclear how habitat fragmentation and loss of forested areas may affect bat populations.

Key Words: Little Brown Bat, *Myotis lucifugus*, Northern Long-eared Bat, *Myotis septentrionalis*, habitat use, tree roosts, Newfoundland.

Typical of isolated islands, insular Newfoundland has relatively few native land mammals, of which a large proportion (21 %, 3 of 14 species) are represented by bats (Northcott 1974). However, little is known about the distribution, relative abundance, or habitat requirements of the three species of bats on Newfoundland (Northcott 1974; van Zyll de Jong 1985). The Little Brown Bat (*Myotis lucifugus*) has been observed over most of the island, and a maternity colony for this species has been monitored on the Avalon Peninsula (Ballam et al. 1993*). The Northern Long-eared Bat (*M. septentrionalis*) is thought to be less common (van Zyll de Jong 1985), and only a single occurrence of the Hoary Bat (*Lasiurus cinereus*) has been documented in Newfoundland (Maunder 1988).

Bats require suitable habitat in which to roost and forage. Forest harvesting alters natural bat roosting and foraging areas, which may in turn affect aspects of bat ecology. Research in the Pacific Northwest suggests that some bats are more dependent on older forest stands (Thomas 1988). Recent studies suggest that retaining certain tree species is necessary for suitable roost sites for some bats, whereas other species appear quite flexible in their roosting requirements (Barclay and Brigham 1996*). Conversely, openings and edge habitat are important feeding sites for many bats (Fenton 1990), and these areas are created by forest harvesting (Brigham et al. 1997; Grindal and Brigham 1998). These and other investigations have led to the recognition that some bat species are sensitive to habitat modifications. Therefore, information on the diversity, distribution, and habitat requirements of bats is essential for the development of forest management practices that will preserve bats as a valuable component of Newfoundland's biodiversity.

The purpose of this study was to expand on a previous preliminary bat survey (Dennis 1994*), as well as further describe the roosting and foraging habitat use by bats in western Newfoundland. As no published information exists on habitat use by bats in Newfoundland, particularly in forest ecosystems, this study represents one of the few documentations of bat ecology in this province.

Methods

The study took place from June to August 1995 at two sites (Marten Pond: 48°38′ N, 57°49′ W; and Kennedy Lake: 49°16′ N, 57°52′ W) in the Western Newfoundland Model Forest, Newfoundland. These areas are found in the Western Newfoundland Ecoregion, with vegetation dominated by Balsam Fir, *Abies balsamea*, Black Spruce, *Picea mariana*, and White Birch, *Betula papyrifera* (Meades and Moores 1989). Elevation ranged from 210–350 m, and the landscape contained numerous lakes and creeks. The two study sites were located within active forest har-

*See Documents Cited section

TABLE 1. Age, sex, and reproductive classes of bats captured in western Newfoundland during 1995. NP = not pregnant, P = pregnant, L = lactating, PL = post-lactating.

	Adult Female				Adult Male	Juvenile Female	Juvenile Male	Total
	NP	P	L	PL				
M. lucifugus	5	2	0	12	3	6	2	30
M. septentrionalis	0	0	0	4	2	4	5	15
Total	5	2	0	16	5	10	7	45

vesting areas, resulting in a forest landscape mosaic of highly fragmented habitat from numerous years of harvesting (most occurring 5–20 y ago). In harvested areas, patches of non-commercial tree species were typically left standing in cutblocks.

Capture

Bats were captured in mist-nets set for a minimum of 2 h after dusk in potential bat flight corridors and foraging areas (e.g. near lake edges and over creeks). I identified bat species and recorded five variables (mass, forearm length, sex, reproductive condition, and age-class). Reproductive condition of the females was determined as either pregnant (estimated by palpation of the abdomen), non-pregnant (unswollen, furred nipples), lactating (swollen pink nipples), or post-lactating (unswollen, bare nipples; Racey 1988). Juveniles were determined by incomplete ossification of the third metacarpal-phalangeal joint (Anthony 1988).

Ultrasonic Detectors

I used Mini-2® ultrasonic bat detectors (Ultra Sound Advice, London, England) to monitor bat activity for 120 min after sunset. These instruments detect the high frequency sound that bats produce when traveling or searching for prey, and can be used to assess relative activity levels (Thomas 1988). Detectors were placed at ground level on lake edges, and orientated with microphones at a 45° angle directed over the water.

I differentiated bat species groups based on the pulse rate and frequency of echolocation calls. At each sample site, a pair of detectors was set at 20 kHz (to identify *L. cinereus*) and 45 kHz (to identify *M. lucifugus* or *M. septentrionalis*; Thomas and Laval 1988). Using Mini-2 bat detectors, it was not possible to distinguish between *M. lucifugus* and *M. septentrionalis* (Thomas et al. 1987).

Two activity types of bats were determined by the pulse rate of echolocation calls. Commuting passes were identified by a steady series of echolocation calls (two or more), produced when bats are traveling or searching for prey. Foraging attempts were identified by a rapid series of echolocation calls, produced when bats make a feeding attempt (Griffin 1958). Temperature at sunset was determined using alcohol thermometers placed 0.5–1 m above the ground.

Radio-telemetry

To locate and monitor roost sites, I affixed miniature radio transmitters (0.44 g, life of approximately 10 d; Holohil Systems Ltd., Woodlawn, Ontario) to the backs of captured bats using small amounts of Skin Bond® (Canadian Howmedica, Guelph, Ontario) surgical adhesive. On subsequent days, I tracked bats to their roosts in order to characterize roosting habitat.

The following roost habitat characteristics were recorded: cavity (type, height, aspect, number), tree (species, height, diameter at breast height (dbh), live/dead class, percent bark remaining, and emergent above/below canopy class), and forest stand (species composition, age-class, slope, and distance to nearest water source and cutblock). Heights and slopes were measured using a clinometer. Percent bark remaining on the tree was estimated visually. Stand age-classes were obtained from forest cover maps. I defined a water source as a body of water large enough for a bat to forage over, or drink from (e.g., lake or creek ≥ 2 m wide).

To assess the availability of potential roosting habitat, I measured trees within circular plots (10 m radius) established at 50 m intervals along 150 m transects. Transects were located in randomly chosen sites in two areas: cutblocks (0–20 y old) and undisturbed forest (81+ y, dominated by Balsam Fir). To eliminate edge effects, transects were located at least 100 m from edges within the two respective habitats. Within each plot, I recorded details of all potential roosts (number, species class as either conifer or deciduous, height class in 5 m increments, dbh, number of cavities, percent bark remaining). I defined a potential roost as a standing dead tree, with a height greater than 2 m and a dbh greater than 0.1 m. This definition was based on the characteristics of known roost trees documented during this study.

Once located by telemetry, roosts were verified by watching the tree for the emergence of bats. Observers (usually two) recorded the number of bats emerging until at least 30 min after sunset, or until too dark for viewing. Roost residency time was determined by the number of consecutive days that a bat remained in the same roost, not including the first roost located. Roost fidelity (the number of roosts used by an individual bat over time) was estimated by using only data in which individuals were

TABLE 2. Characteristics of known and potential roost trees in western Newfoundland in 1995. Mean (±1 SE) values are presented when applicable. Statistical significance represented by: * ($p < 0.001$) or NS (not significant). Dashes represent irrelevant or uncollected data.

	Characteristic	Known Roosts	Potential Roosts Forest	Potential Roosts Cutblock	Significance
Cavity	height (m)	4.2 (0.89)	-	-	-
	cavities (#)	4.0 (1.2)	0.18 (0.04)	0.17 (0.05)	*
Tree	height (m)	8.7 (1.2)	11-15	11-15	see Fig. 2
	conifer	5[1]	228	53	NS
	deciduous	1[1]	13	31	NS
	bark remaining (%)	55 (13.8)	52.9 (2.5)	43.9 (4.7)	NS
	dbh (cm)	29.1 (2.6)	23.6 (0.48)	25.9 (1.1)	NS
Stand	slope (%)	15 (2.4)	11.5 (0.37)	11.9 (0.64)	NS
	distance to cutblock (m)	10.6 (4.5)	-	-	-
	distance to water (m)	259 (107.5)	-	-	-
	# trees/ha	-	191.9	66.9	-
n		8	241	84	-

[1]species (#) for known roosts: Balsam Fir (4); Black Spruce (1); White Birch (1); unidentifiable (2).

monitored for more than two days, and known to move between roosts. On topographical maps, linear distances were calculated between roost and foraging or capture sites, as well as distances between multiple roost sites for an individual bat.

I used t-tests to examine differences between characteristics of known and potential roosts (Zar 1984). Chi-square tests were used to examine differences between roost height classes and tree species type. I used a 0.05 rejection level in all cases.

Results

Capture

Mist-nets were set on 23 nights for a total of 143 mist-net hours (one mist-net hour = one 2 m × 6 m net set for one hour) at 15 different locations (e.g., lake edges, creeks). This resulted in the capture of 48 bats, three of which were recaptures (Table 1). *M. lucifugus* were captured more often (67%) than *M. septentrionalis* (33 %).

Sex and age-class structure was not equally distributed for captured bats. Adult females were captured more frequently than adult males (*M. lucifugus* — 6.3 females:1 male; *M. septentrionalis* — 2 females:1 male). Juveniles represented 27% and 60% of captures for *M. lucifugus* and *M. septentrionalis*, respectively (Table 1).

Ultrasonic Detection

Bat detectors were used on 24 nights for a total of 72 h at 36 sites, resulting in the detection of 1393 commuting passes and 271 foraging attempts. No passes were detected at 20 kHz (frequency setting to detect *L. cinereus*). Bat activity was recorded at 87 % of the sites sampled, although at relatively low levels (mean ± 1 SE): commuting passes/hour (19.4 ± 11.4); foraging attempts/hour: (3.8 ± 3.0). Bat activity did not begin until at least 20 min after sunset, then generally peaked 45 min after sunset and declined over the remaining 75 min of observation time.

Mean (± 1 SE) temperature at sunset was 13.7°C (0.77) and ranged between 5 and 22°C, with most (87% of nights) temperatures above 10°C. In June, bat activity was regularly observed at cooler temperatures between 2 and 6°C later in the night.

Roosting Habitat

Radio transmitters were attached to 11 *M. lucifugus* (9 females, 4 males) and 4 *M. septentrionalis* (3 females, 1 male). Mean mass (g ± 1 SE) of *M. lucifugus* and *M. septentrionalis* carrying radio transmitters was 8.1 (0.2) and 7.7 (0.3), respectively. Of the 15 radio-tagged bats, eight different roosts were located from seven individual female bats (4 *M. lucifugus* and 3 *M. septentrionalis*; Table 2). Mountainous terrain and poor accessibility limited the success of monitoring radio-tagged bats. Because of the low number of roosts, both bat species were combined for the following analyses of roost characteristics.

Bats roosted in old woodpecker holes (n = 4), in cracks in tree trunks (n = 2), and under peeling bark (n = 2), all of which were located at least half of the tree height. Roost cavities faced SW (n = 4), SE (n = 2), or NE (n = 2). Four of the roosts were in Balsam Fir trees, and 83% of identifiable roost trees were coniferous. All roosts were located in dead standing trees in either forests greater than 81 y, or in cutblocks less than 20 y old. Most roosts (87.5 %, n = 7) were less than 15 m from cutblock/forest edges (Table 2). Although distance to water sources (lakes or creeks) varied greatly (Table 2), 75 % (n = 6) were less than 250 m from sources.

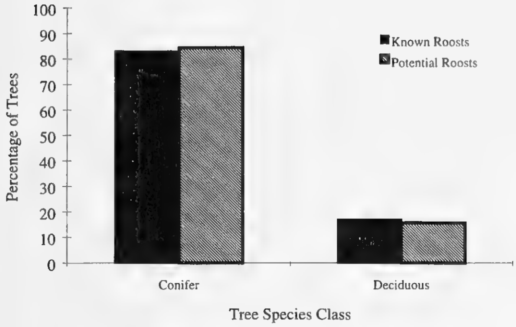

FIGURE 1. Species type composition of known (n = 8) and potential (n = 325) roost trees in western Newfoundland in 1995.

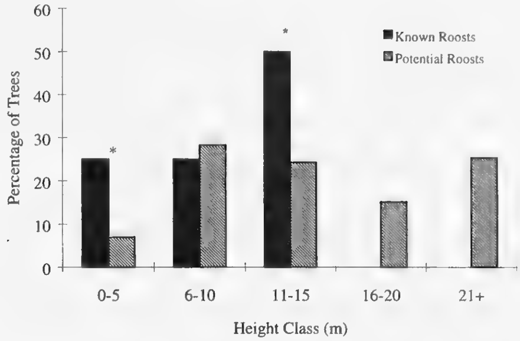

FIGURE 2. Height class distribution of known (n = 8) and potential (conifer or deciduous combined, n = 325) roost trees in western Newfoundland in 1995. * represents a significant difference (p>0.05) within each height class.

To assess the quantity and quality of potential roosts available to bats, ten transects were conducted in each of the forest and cutblock habitats for a total of 80 plots. The forest had almost three times the density of potential roosts than the cutblock (Table 2).

There were no significant differences between known and potential roosts for most comparable characteristics (% bark remaining, dbh, or stand slope; Table 2). Furthermore, roost tree species were used in approximately the same proportions as were available to bats (Figure 1, Table 2). However, smaller height classes (0–5 and 10–15 m) of roost trees were selected, compared to those available (0–5 m: $\chi^2 = 10.1$, df = 2, $p < 0.005$; 11–15 m: $\chi^2 = 9.28$, df = 2, $p < 0.005$; all other height classes $p > 0.05$; Figure 2), and only 50% of known roosts extended above the surrounding canopy height (Table 2). Known roosts had significantly greater numbers of cavities than potential roosts (F = 102.3, df = 2, $p < 0.001$).

Bats used numerous roosts and moved almost daily between roosts during the monitoring period. Mean number of roosts used by each bat was 0.79 roosts/day (SE = 0.09, n = 5 bats at 19 roosts). Mean residency time at the same roost for individual bats was 1.44 d (SE = 0.29, n = 4 bats at 9 roosts). Colony sizes were generally larger for *M. septentrionalis* (mean 21, SE = 13.1, n = 3 roosts) than *M. lucifugus* (mean 5.0, SE = 1.5, n = 7 roosts).

Bats which were monitored stayed close to foraging areas and other roost sites. Mean linear distance of roost to foraging or capture site was 560 m (SE = 153, n = 8). Mean linear distance between multiple roosts sites for the same individual was 410 m (SE = 48, n = 7). Note that in the above calculations (roost fidelity, roost residence time, and distances), different bats moved between, and used the same roosts.

Discussion

Diversity and Activity Patterns

Only *M. lucifugus* and *M. septentrionalis* were captured or detected, supporting previously known bat diversity measures for Newfoundland. However, *M. septentrionalis* appear to be more abundant than previously thought, representing a third of captures in this study. The absence of *L. cinereus* from this survey suggests its occurrence is rare in western Newfoundland, or may simply be accidental, as represented by the single record in St. John's (Maunder 1988).

Bat activity was observed at most sample sites, but at relatively low levels, suggesting that myotis bats are well distributed in western Newfoundland, but at low abundance. For example, bat activity from this study is low when compared to myotis activity levels from other studies using similar sampling methodology in south west Ontario (80.4 passes/hr, Hickey and Neilson 1995), south west Alberta (approximately 60 passes/hour, von Frenkell and Barclay 1987), southern British Columbia (approximately 150 passes/hr, Grindal 1996*), and north east British Columbia (28.8–188 passes/hr, Crampton et al. 1997*).

The relatively low bat abundance measures inferred from detector data, and the foraging activity recorded at low temperatures, may be due to the relatively short summer season that bats experience in Newfoundland. Bat activity is generally thought to decrease dramatically at temperatures below 10 to 12° C, most likely due to low insect availability (Rachweld 1992; R. M. Brigham, personal communication). However, I regularly observed bats foraging in Newfoundland at low temperatures (2 – 6°C). Therefore, in this boreal ecoregion, bats may be forced to forage in extreme conditions (i.e., low temperatures, with presumably low levels of prey) to gain sufficient resources for growth, reproduction, and hibernation. For example, at Cochrane Lake in eastern Newfoundland, maternity colonies break up in late August, with no bats present in maternity roosts by mid-September (Wildlife Division, St. John's, unpublished data). The cool temperatures recorded during June and July, coupled with the relatively early dates of maternity colony break up, reflect the short active season for bats in Newfoundland, and may explain the relatively low bat activity levels.

The sex and age-class data suggest that maternity colonies occurred within the study site. Most individuals captured were females or juveniles, which typically roost in maternity colonies separate from adult males during the summer months (Kunz 1982). Further, the high frequency of roost switching, together with the use of multiple roosts sites occupied by relatively few individuals, suggest that individuals may have been dispersing from maternity colonies. In addition, only females were monitored at roosts, suggesting that all known roosts were maternity colonies, or tertiary maternity colonies used during the break-up period. The timing of events interpreted from my data are consistent with those from eastern Newfoundland when juveniles become volant and leave the roost (late July), and maternity colonies are breaking up (late August: Wildlife Division, St. John's, unpublished data).

Roosting Habitat

Bats roosted exclusively in dead standing trees and did not select roosts based on tree species, as the known roost trees were in proportion to those species available. However, bats preferred roosts with greater numbers of cavities than those of potential roosts. These cavities, presumably created by woodpeckers and other primary cavity excavators, provide suitable sites for maternity colonies (Kunz 1982). The cavities tended to face south, which would result in passive thermal heating from direct solar radiation. These warm conditions facilitate embryo and juvenile development (Kunz 1982; Kurta et al. 1989; Racey and Swift 1981), and reduce energetic expenditures of adults through decreased thermoregulatory costs. Therefore, reproductive females may benefit energetically by selecting roosts that are heated by the sun.

The spatial distribution of roosts suggests that bats may select sites which are easy to access, and those which are close to alternate roost sites and foraging habitat. Bats may have difficulty flying to, and locating roosts in, interior forest stands due to the spatial complexity of a dense forest canopy and understorey (Brigham et al. 1997). In contrast, roosts located along edge habitat may be more easily located and accessed, explaining the close proximity of roosts to cutblock/forest edges observed in this study. Further, multiple roosts used by the same individuals were spaced relatively close together. Although the data are limited, this may indicate that groups of roosts, as opposed to single trees, were used by bats, as suggested by other studies (Kurta 1982; Vonhof and Barclay 1996). Roost trees were also located relatively close to water sources, which presumably represented primary foraging and/or drinking sites (Grindal 1996*). However, water sources occurred frequently in the study area, and therefore would unlikely be a limiting factor for roost site selection. It is also important to note that only female bats were monitored at their roosts, and other radio-tagged bats (e.g., males) may have roosted and foraged in larger areas.

As most roosts were located close to edge habitat, forest harvesting may increase roost accessibility for some bats by creating corridors or openings in the forest. Conversely, forest harvesting decreases roost availability by removing large blocks of older forest, which typically contain preferred roosting habitat (Grindal 1998). This loss of roosting habitat may be compensated somewhat by the harvesting practice in Newfoundland of leaving individual or groups of standing dead trees (typically non-commercial species) in cutblocks (SDG, personal observation). However, it is still unclear how habitat fragmentation and the overall loss of forested areas may affect bat populations (Grindal and Brigham 1998b).

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Documents Cited

Ballam, D., J. Brazil, G. Yetman, and **K. Brown.** 1993. Observations of a little brown bat (*Myotis lucifugus*) maternity colony in a Provincial Park, Avalon Peninsula, Newfoundland, 1993. Parks Division internal document. Newfoundland Department of Natural Resources, St. John's.

Barclay, R. M. R., and **R. M. Brigham.** 1996. Bats and Forests Symposium: October 19–21, 1995, Victoria, B.C., Canada. Resources Branch, Ministry of Forests, Victoria, British Columbia. Work paper 23/1996.

Crampton, L. H., K. G. Poole, and **C. Shurgot.** 1997. Bat inventory of the Prophet River territory in northeastern British Columbia. A report prepared for B.C. Ministry of Lands and Parks, Fort St. John, British Columbia.

Dennis, W. 1994. Habitat utilization by bats in the boreal forest ecosystem. A report prepared for the Newfoundland and Labrador Wildlife Division.

Grindal, S. D. 1996. Habitat use by bats in fragmented forests. Pages 260–272 *in* Bats and Forests Symposium: October 19–21, 1995, Victoria, B.C., Canada. *Edited by* R. M. R. Barclay and R. M. Brigham. Resources Branch, Ministry of Forests, Victoria, British Columbia. Work paper 23/1996.

Literature Cited

Anthony, E. L. P. 1988. Age determination in bats. Pages 47–57 *in* Ecological and Behavioral Methods for the Study of Bats. *Edited by* T. H. Kunz. Smithsonian Institute Press, Washington D.C.

Brigham, R. M., S. D. Grindal, M. Firman, and **J. Morissette.** 1997. The influence of structural clutter on activity patterns of insectivorous bats. Canadian Journal of Zoology 75: 131–136.

Fenton, M. B. 1990. The foraging behaviour and ecology of animal-eating bats. Canadian Journal of Zoology 68: 411–422.

Griffin, D. R. 1958. Listening in the dark. Cornell University Press, Ithaca.

Grindal, S. D. 1998. Habitat use by bats in second- and old-growth stands in the Nimpkish Valley, British Columbia. Northwest Science *in press*.

Grindal, S. D., and **R. M. Brigham.** 1998a. Short-term effects of small-scale habitat disturbance on activity by insectivorous bats. Journal of Wildlife Management 62: 996–1003.

Grindal, S. D., and **R. M. Brigham.** 1998b. Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. Ecoscience *in press*.

Hickey, M. B., and **A. L. Neilson.** 1995. Relative activity and occurrence of bats in southwestern Ontario as determined by monitoring with bat detectors. Canadian Field-Naturalist 109: 413–417.

Kunz, T. H. 1982. Roosting ecology. Pages 1–55 *in* Ecology of Bats. *Edited by* T. H. Kunz. Plenum Press, New York.

Kurta, A., G. P. Bell, K. A. Nagy, and **T. H. Kunz.** 1989. Energetics of pregnancy and lactation in free-ranging little brown bats (*Myotis lucifugus*). Physiological Zoology 62: 804–818.

Maunder, J. E. 1988. First Newfoundland record of the Hoary bat, *Lasiurus cinereus*, with a discussion of other records of migratory tree bats in Atlantic Canada. Canadian Field-Naturalist 102: 726–728.

Meades, W. J., and **L. Moores.** 1989. Forest site classification manual: A field guide to the Damman forest types of Newfoundland. Ministry of Supplies and Services Canada and Newfoundland Department of Forestry and Agriculture.

Northcott, T. H. 1974. The Land Mammals of Insular Newfoundland. A special publication of the Newfoundland and Labrador Wildlife Division.

Racey, P. A. 1988. Reproductive assessment in bats. Pages 31–43 *in* Ecological and Behavioral Methods for the Study of Bats. *Edited by* T. H. Kunz. Smithsonian Institute Press, Washington D.C.

Racey, P. A., and **S. M. Swift.** 1981. Variation in gestation length in a colony of pipistrelle bats (*Pipistrelle pipistrellus*) from year to year. Journal of Reproduction and Fertility 61: 123–129.

Rachweld, A. 1992. Habitat preference and activity of the noctule bat *Nyctalus noctula* in the Bialowieza Primeval Forest. Acta Theriologica 37: 413–422

Thomas, D. W. 1988. The distribution of bats in different ages of Douglas-fir forests. Journal of Wildlife Management 52: 619–626.

Thomas, D. W., and **R. K. Laval.** 1988. Survey and census techniques. Pages 77–90 *in* Ecological and Behavioral Methods for the Study of Bats. *Edited by* T. H. Kunz. Smithsonian Institute Press, Washington D.C.

Thomas, D. W., G. P. Bell, and **M. B. Fenton.** 1987. Variation in echolocation call frequencies recorded from North American vespertilionid bats: A cautionary note. Journal of Mammalogy 68: 842–47.

van Zyll de Jong, C. G. 1985. Handbook of Canadian Mammals 2: Bats. National Museum of Natural Sciences, National Museums of Canada, Ottawa.

von Frenckell, B., and **R. M. R. Barclay.** 1987. Bat activity over calm and turbulent water. Canadian Journal of Zoology 65: 219–222.

Vonhof, M. J., and **R. M. R. Barclay.** 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74: 1797–1805.

Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall Inc., Englewood Cliffs, New Jersey.

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Effect of Organic Matter Removal, Ashes and Shading on Eastern Hemlock, *Tsuga canadensis*, Seedling Emergence from Soil Monoliths Under Greenhouse Conditions

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The effects of organic matter removal, ashes and shading were investigated on Eastern Hemlock (*Tsuga canadensis* (L.) Carr.) emergence using soil monoliths in greenhouse conditions. Two hundred (18 cm width x 30 cm length x 25 cm depth) soil monoliths (50 from each of four sites) were transported to a greenhouse where treatments consisting of 0%, 25%, 50%, 75% and 100% organic horizon removal were performed. One half of each monolith contained ashes generated from the removal of organic matter and its *ex situ* burning whereas the other half was left without ashes. After seeding, the monoliths were placed under three different shading levels [100% Photosynthetically Active Radiation (PAR), 66% PAR and 33% PAR]. *Tsuga canadensis* emergence was greatest under the 33% PAR level after 50%, 75% and 100% organic horizon removal. Emergence appeared to be lowest on monoliths with no organic horizon removal exposed to 100% PAR. Ash did not affect hemlock germination. Therefore, *T. canadensis* regeneration can be achieved under high shading and moderate organic horizon removal.

Key Words: Eastern Hemlock, *Tsuga canadensis*, seedlings, regeneration, fire, Ontario.

Eastern Hemlock (*Tsuga canadensis* (L.) Carr.) is a slow-growing, long-lived shade tolerant species that can live 800 years or more (Godman and Lancaster 1990). Its northern range follows that of the Great Lakes-St Lawrence forest region and its southern range extends to Georgia, USA. It is found from sea-level in the northern part of its range to 910 m in the southern part (Godman and Lancaster 1990). Management and conservation of Eastern Hemlock are growing concerns because of dwindling stocks throughout its range. Indeed, pre-settlement Eastern Hemlock stands have been greatly reduced by extensive logging, browsing by animals, wildfire, and regeneration failure after various types of disturbance (Alverson et al. 1988; Anderson and Loucks 1977; Eckstein 1980; Findel et al. 1960; Kershaw and Gordon 1991; Mladenoff and Stearns 1993; Russell et al. 1993; Wiant 1980). In the northern Lake States, USA, hemlock stands once were a dominant feature of the landscape, whereas they now comprise less than 0.5% of the forest types (Eckstein 1980). Non-regenerating hemlock stands were replaced by northern hardwood stands or aspen-birch stands (Curtis 1959).

A consistent seed producer, Eastern Hemlock regeneration is limited by its strict germination and emergence requirements (Godman and Lancaster 1990). In undisturbed sites, suitable microsites for hemlock regeneration are well-decomposed litter, rotten wood, mineral soil, or moist moss mats (Wiant 1980) Ideal sites for hemlock regeneration are created by scarification or by prescribed burning (Godman and Lancaster 1990), otherwise regeneration is limited to rotten logs, stumps, mounds that have a better moisture retention, and warmer surfaces than the forest floor.

Although the general conditions for hemlock regeneration are known there is a need to understand further its seedbed requirements (Kershaw and Gordon 1990) to develop new approaches for its management and conservation, particularly under climate change. Indeed, climate change is expected to lead to drier growth conditions throughout the range of Eastern Hemlock (Schwartz 1991). Recently, we developed an *in vitro* method to assess seedbed requirements of conifer species using undisturbed blocks of soils, termed soil monoliths, in greenhouse conditions (Herr and Duchesne 1995, 1996; Herr et al. 1995). This method offers a great opportunity to further understand hemlock germination requirements under various types of conditions, hence to promote its conservation through improved management and restoration. The objective of this investigation is to determine the relationship between organic horizon thickness, moisture regime, and shading on Eastern Hemlock seedling emergence.

Materials and Methods

Monolith collection

Germination requirements were studied using soil monoliths collected in Central Ontario as described elsewhere (Herr and Duchesne 1995, 1996; Herr et al. 1995). Briefly, soil monoliths were collected from four ecosystems dominated by *T. canadensis* (Table 1). Each site has been described by Ontario Ministry of Natural Resources Forest staff under MNR Ecological Classification System (B. Chambers, personal communication, available through Ministry of Natural Resources). These sites were selected to cover the natural variation in soil moisture conditions encountered in hemlock stands at the northern end of its range. Fifty soil monoliths were collected from each of the four sites for a total of 200 monoliths. Monoliths from Finlayson and Canisbay townships were harvested on 2 November 1994 whereas monoliths from Gladstone were harvested on 14 November 1994.

For monolith collection, a wooden board measuring 18 cm by 30 cm and 2 cm deep was gently placed on the litter to avoid excessive disturbance. Monoliths were then cut out to a minimum depth of 25 cm using a 30 cm serrated knife in order to include the organic horizons [L (litter), F (fermentation), and H (humification)], the Ae horizon, and part of the B horizon which are typical of podzolic soils (Anonymous 1978). Once excavated, the monoliths were wrapped in weed barrier nursery cloth, and placed into Rootrainer boxes (Spencer-Lemaire Industries Ltd., Edmonton, Alberta). Following collection, the monoliths were left in the dark at approximately 20°C for six weeks to ensure drying of the organic matter before organic horizon removal began. In past experiments we found that *ex situ* burning of organic matter is easier achieved on dry material.

Organic horizon removal

Thickness of organic matter (LFH horizons) of each monolith was measured and different thicknesses (100%, 77%, 50%, and 25%) of the organic horizon were removed from the monoliths to determine the effect of organic horizon thickness on seed emergence. Note that 50% humus removal treatment eliminated the L and F layers for all four ecosystem types. The appropriate thickness of the organic horizon was removed using a 30 cm serrated knife. For each collection site (50 monoliths/site), nine monoliths received each of the removal treatments (36 monoliths), nine monoliths were not subjected to organic horizon removal and five monoliths were kept as controls to evaluate the presence of soil seed bank, for a total of 50 monoliths for each of the four sites.

To determine the effect of ashes on hemlock germination, the portions of organic horizon removed were combined for each treatments (i.e., all 25% organic horizon removal portions were combined) and burned *ex situ* using a propane torch in a fume hood until no further combustion was attainable. The total mass of ashes for each set of removal treatments from each site (25%, 50%, 75%, and 100%) was divided by the number of monoliths contributing to that particular treatment, and then half of that mass was spread as an uniform layer onto half of the area of each monolith. This created two treatments for each monolith: an organic horizon removal with ash present, and an organic horizon removal with ash absent. The two treatments were separated with plastic dividers to prevent the ashes from spilling over onto the adjacent half of the monolith. The monoliths were then left in the dark for two months, until *T. canadensis* were ready for sowing. Two weeks before sowing, the monoliths were transferred to a greenhouse in mid May 1995, and watered daily (see below for the moisture regime) to provide initial moisture to the germinating seeds.

Each half of the 200 monoliths (one side with ashes present and one side without ash) was seeded with 116 stratified eastern hemlock seeds (100 viable seeds) [Petawawa National Forestry Institute (PNFI) seedlot numbers 8430073.0 and 8430074.0], with an average germination of 86%. Seeds from the PNFI seedbank were used because of the extensive labour that would have been required to harvest large amount of Hemlock seeds from our research sites. These two seedlots were used as a mixture because of the rarity of large hemlock seedlots in the PNFI seed bank. Stratification was conducted by soaking seeds for 24 h in 0.1 % (w/v) Benlate in distilled water. The seeds were then air-dried for 4 h and placed in Ziplock™ bags for 90 days at 4°C in the dark.

After seeding in late May 1995, the monoliths were kept in a greenhouse at ambient air temperature (monolith surface 23.8 ± 4.3°C without shade). Watering of the monoliths was conducted daily based on the June precipitation records over a 30-year period from the Bransted weather station at PNFI, approximately 10 km from Algonquin Park (G. Péch, personal communication). This precipitation regime was applied to all monoliths, regardless of their original collection site, to create uniform watering conditions, thus ensuring comparability of the results from different ecosystem types. As well, it is similar to the June precipitation regime of the Algoma district. At PNFI, June is the month of the growing season with the highest rainfall (Weber et al. 1987) . Therefore, this value was used as the best case scenario for seed emergence. As well, in distributing the average June rainfall over 30 days, we recognize that we provided a best case scenario for soil moisture regime because rainfall events are rarely distributed evenly throughout the month. The average daily June precipitation of 2.7 mm per day was adjusted for the entire (18 cm × 30 cm) surface of the monolith, yielding a watering schedule of 145 mL deionized water per monolith per day. Preliminary results showed that no germination took place when the monoliths were exposed to less rain-

TABLE 1. Description of monolith collection sites in Ontario.

Location	Basal area	Soil texture	Moisture	Soil depth	Humus form	Depth of LFH
Finlayson Township, Algonquin Park Latitude: N45.446011 Longitude:W78.769920	64% *Tsuga canadensis* 20% *Thuya occidentalis* 8% *Abies balsamea* 2% *Acer saccharum* 1% *Acer rubrum*	Silty	moderately fresh	> 93 cm	Fibrihumimor	11 cm
Finlayson Township, Algonquin Park Latitude: N45.446011 Longitude:W78.769920	42% *Acer saccharum* 28% *Tsuga canadensis* 28% *Acer rubrum* 1% *Ostrya virginiana*	Fine sandy	dry	34 cm	Fibrihumimor	15 cm
Canisday Township, Algonquin Park Latitude: N45.548088 Longitude:W78.567322	95% *Tsuga canadensis* 4% *Betula alleghaniensis* 1% *Thuya occidentalis*	Medium loamy	fresh	93 cm	Humimor	11 cm
Gladstone Township, Algoma District Latitude: N46.31428 Longitude:W83.252365	59% *Tsuga canadensis* 13% *Acer saccharum* 9% *Betula papyrifera* 9% *Acer rubrum* 7% *Thuya occidentalis* 3% *Picea glauca*	Silt loam	dry	28 cm	Fibrihumimor	9 cm

fall than the PNFI rainfall regime. Therefore, we found no need to further assess the effect of reduced precipitation regimes on *T. canadensis* (Herr et al. 1995, 1996).

Shading

To evaluate the effect of shading on Eastern Hemlock germination, the monoliths were exposed to either 100%, 66% or 33% photosynthetically active radiation (PAR) in greenhouse conditions. This simulates the light regimes of clear-cuts, shelterwood cuts, and some undisturbed stands, respectively. One hundred and eighty monoliths were used [45 from each of the four sites distributed as nine monoliths for each of the 0%, 25%, 50%, 75%, and 100% removal treatments], with three separate shading levels performed simultaneously, each in a randomized complete block design. Replication of the shade factor was not possible due to greenhouse space limitations; therefore, statistical comparisons could not be made among the three different shading levels. Shading was accomplished by suspending wooden lattices 60 cm above the monoliths. Measurement of PAR at solar noon above and below the lattice was accomplished with a Li-Cor LI-190SB Quantum sensor (Li-Cor, Lincoln, Nebraska, USA); the number of slats in the lattice was then adjusted to obtain the desired PAR level.

Twenty untreated monoliths (0% organic horizon removal) were placed under a 33% PAR levels, and also watered with 145 mL deionized water per day (June average daily rainfall) for four weeks to determine the presence and level of the Eastern Hemlock soil seedbank. This shading level was selected because in previous experiments (Herr and Duchesne 1995, 1996), it provided optimal conditions for germination of conifer seeds in the soil seedbank (unpublished results).

Seedling emergence was monitored twice per week and emerged seedlings were removed from the experiment to prevent competition. Seedlings were considered to have emerged when the seed coat was lifted above the substrate by the hypocotyl and this was the basis for calculating percent emergence. Total percent Eastern Hemlock seedling emergence was determined at the end of June 1995 when no further seeds emerged, four weeks after the beginning of the experiment. For statistical analysis of percent emergence, the data were arcsine-transformed and tested for homoscedasticity to satisfy ANOVA prerequisites, and analysed using the PROC GLM procedure of SAS (SAS Institute Inc., 1985). To test for significant differences among means, the Tukey's HSD multiple comparison test was used (= 0.01).

Results

There was no statistical difference at ($P < 0.10$) in hemlock emergence among the sites, therefore, the data from all sites was pooled. Hemlock seedling emergence was significantly ($P < 0.001$) affected by organic matter removal and there was a tendency toward an effect of PAR levels (Table 2) but emergence was not affected by the presence of ash (data not shown). Hemlock germination significantly increased with organic matter removal under the 33% PAR level whereas there was no effect of organic horizon removal under the 66% and 100%

TABLE 2. Effect of organic horizon removal and shading on percent emergence of *Tsuga canadensis* on soil monoliths from four ecosystem types in Ontario.

	Organic matter removal				
Treatment	0%	25%	50%	75%	100%
all PAR[++]levels	3.2a[+]	5.4a	9.9a	12.2a	12.7a
33% PAR	8.1a	11.8b	24.4a	32.9b	36.6b
66% PAR	1.0a	4.1a	4.8a	2.9a	0.33a
100% PAR	0.37a	0.19a	0.42a	0.93a	0.19a

[+]Within rows, averages followed by a different letter are significantly different at P<0.05 using Tukey's multiple comparison procedure.
[++]PAR—photosynthetically active radiation

PAR levels (Table 2). Germination was highest on the 50%, 75% and 100% organic horizon removal treatments exposed to 33% PAR (Table 2). There was no ash * removal interaction at any of the PAR levels. No hemlock seedling emerged from the 20 untreated monoliths. Therefore, no corrections to the final emergence data were necessary to account for the presence of a natural soil seedbank.

Discussion

Although the difficulties of regenerating Eastern Hemlock are well recognized, there is no consensus as to their reason (Alverson et al. 1988; Anderson and Loucks 1979; Eckstein 1980; Findel et al. 1960; Kershaw and Gordon 1991; Mladenoff and Stearns 1993; Wiant 1980). Lack of hemlock regeneration has been attributed to browsing (Alverson et al. 1988), lack of available soil moisture (Tubbs 1978), allelopathy (Ward and McCormick 1982), lack of cover provided by understory vegetation (Maguire and Forman 1983), and nutrient deficiencies (Kershaw and Gordon 1991). In this investigation, hemlock emergence was greatest after a minimum of 50% organic matter removal and under reduced PAR.

Eckstein (1980) reports that the radicle of germinating seedlings has great difficulty penetrating even a small thickness of forest litter made by maple or even hemlock litter, a substrate subjected to large seasonal and daily moisture fluctuations (Barnes 1991). In this investigation we observed that sunlight and organic matter had a negative impact on seed germination. Therefore, we hypothesize that the negative effect of organic horizon, particularly the L and F layers, and full sunlight on emergence is caused by a lack of available water for germination. Presumably, organic horizon removal treatments that eliminated the L and F layers (50%, 75% and 100% removal) favoured hemlock germination. Interestingly, the results from the current investigation suggest that hemlock is more sensitive to drought than Jack Pine (*Pinus banksiana* Lamb.) and Red Pine (*Pinus resinosa* Ait.) (Herr and Duchesne 1995, 1996). Thus, climate change caused drought may be more detrimental to Eastern Hemlock than the former two pine species.

One silvicultural implication of our findings is that hemlock management must aim toward reducing organic matter, mostly the leaf litter and the fermentation layers while keeping adequate cover to favour the natural regeneration of this species. Current accepted silviculture of Eastern Hemlock stands on dry sites is achieved through partial cutting systems, either a three to four cut shelterwood system or selection cuts (Anderson et al. 1990; Tubbs 1978) that create small canopy gaps (McClure and Lee 1993) leading to no more than 33% PAR at ground level. Also results do not support the hypothesis that hemlock emergence is greatest on mineral soil (Tubbs 1978). Rather they demonstrate that the upper organic layers should be removed to help germination.

Although in our experimental conditions Eastern Hemlock germination was enhanced by organic matter removal and it was unaffected by ashes, the use of prescribed burning in its management (Godman and Lancaster 1990) must be orchestrated carefully. Contrary to fire-dependent species such Red Pine and Jack Pine, Eastern Hemlock trees have thin bark and a shallow root system which make them highly sensitive to wildfire (Rogers 1978). Records show that only low intensity fires favour the creation of even-aged stands (Miles and Smith 1960; Rogers 1978). However, pre-settlement even-aged hemlock stands were relatively rare (Rogers 1978) and fire return intervals were as long as 2778 years (Whitney 1987), suggesting that wildfire did not play a significant role in the establishment of this species. Therefore, the use of fire on hemlock management must be conducted under weather and fuel conditions that favour low fire intensities. Moreover, because hemlock germination requires shade, it would be advisable to use prescribed burning only in understorey conditions. For this, however, it will be important to determine optimal fire weather conditions that are best suited for overstory tree survival and organic matter reduction.

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Literature Cited

Alverson, W. S., D. M. Walter, and **S. L. Solheim.** 1988. Forests to deer: edge effects in Northern Wisconsin. Conservation Biology 2: 248–258.

Anderson, R. C., and **O. L. Loucks.** 1979. White-tailed deer (*Odocoilus virginianus*) influence on structure and composition of *Tsuga canadensis* forests. Journal of Applied Ecology 16: 855–861.

Anderson, H. B., D. B. Batchelor, C. M. Corbett, A. S. Corbett, D. T. Deugo, C. F. Husk, and **W. R. Wilson.** 1990. A silvicultural guide for the tolerant hardwoods working group of Ontario. Forest Research Group. Ontario Ministry of Natural Resources. North Bay, Ontario. 179 pages.

Anonymous. 1978. The Canadian system of soil classification. Canadian Ministry of Agriculture publication number 1646. Ottawa. 170 pages.

Barnes, B. V. 1991. Deciduous forests of North America. Pages 219–344 *in* Temperate deciduous forests. *Edited by* E. Röhrig and B. Ulrich. Elsevier, Amsterdam. The Netherlands.

Curtis, J. T. 1959. The vegetation of Wisconsin: an ordination of plant communities. University of Wisconsin. Press. Madison. 657 pages.

Eckstein, R. G. 1980. Eastern hemlock in north central Wisconsin. Wisconsin Department of Natural Resources Report 104. Madison. 20 pages.

Godman, R. M., and **K. Lancaster.** 1990. Eastern hemlock. Pages 604–612 *in* Silvics of North America. Volume 1, conifers. United States Department of Agriculture Forest Service Agriculture Handbook 654.

Herr, D. G., and **L. C. Duchesne.** 1995. Effect of water regime, cover, organic horizon thickness, and ashes on jack pine seedling emergence. Water, Air and Soil Pollution 82: 147–154.

Herr, D. G., and **L. C. Duchesne.** 1996. Effect of organic horizon thickness, shading, ashes and watering regime on red pine seed emergence. Canadian Journal of Forest Research 26: 422–427.

Herr, D. G., J. L. Cooper, L. C. Duchesne, and **R. J. Reader.** 1995. Modelling seedling emergence using soil monoliths. Petawawa National Forestry Institute Technical Report number 17. 12 pages.

Kershaw, H. M., and **A. Gordon.** 1991. Analysis of the status of Eastern Hemlock *(Tsuga canadensis* (L.) Carr.) and its requirements. Central Ontario Forest Technology Development Unit Technical Report number 18. 87 pages.

Maguire, D. A., and **R. T. T. Forman.** 1983. Herb cover effects on tree seedling patterns in a mature hemlock forest. Ecology 64: 1367–1380.

McClure, J. W., and **T. D. Lee.** 1993. Small-scale disturbance in a northern hardwoods forest: effects on tree species abundance and distribution. Canadian Journal of Forest Research 23: 1347–1360.

Miles, M. C., and **E. C. Smith.** 1960. A study of the origin of hemlock forests in southwestern Nova Scotia. The Forestry Chronicle 36: 375–392.

Mladenoff, D. J., and **F. Stearns.** 1993. Eastern hemlock regeneration and deer browsing in the northern Great Lakes region: a re-examination and model situation. Conservation Biology 7: 889–900.

Russell, E. W., R. B. Davis, R. S. Anderson, T. E. Rhodes, and **D. S. Anderson.** 1993. Recent centuries of vegetational change in the glaciated north-eastern United States. Journal of Ecology 81: 647–664.

Schwartz, M. W. 1991. Potential effects of global climate change on the biodiversity of plants. The Forestry Chronicle 68: 462–471.

Tubbs, C. H. 1978. How to manage Eastern Hemlock in the Lake States. United States Department of agriculture, Forest Service North Central Experimental Station Information Pamphlet. 2 pages.

Ward, H. A., and **L. H. McCormick.** 1982. Eastern hemlock allelopathy. Forest Science 28: 681–686.

Weber, M. G., M. Hummel, and **C. E. Van Wagner.** 1987. Selected parameters of fire behaviour and *Pinus banksiana* Lamb. regeneration in eastern Ontario. The Forestry Chronicle 63: 340–346.

Whitney, G. G. 1987. An ecological history of the Great Lakes forest of Michigan. Journal of Ecology 75: 667–684.

Wiant, H. V. 1980. Eastern Hemlock. Page 27 *in* Forest Cover Types of the United States and Canada. *Edited by* F. H. Eyre. Society of American Foresters, Washington, D.C.

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The New Porcupine Forest Flock of Trumpeter Swans, *Cygnus buccinator*, in Saskatchewan

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Trumpeter Swans, *Cygnus buccinator*, have established a nesting population in the Greenwater Park - Porcupine Forest Area of Saskatchewan. Further expansion of the population into available habitat might not occur because of lack of winter habitat being used by Trumpeter Swans. The long-term decision regarding management of Trumpeter Swans must be shared between the Canadian Wildlife Service, the United States Fish and Wildlife Service and the Wildlife agencies in the provinces and states where the swans currently nest, winter and could potentially winter.

Key Words: Trumpeter Swans, *Cygnus buccinator*, breeding, distribution, status, Saskatchewan.

There are two native and one introduced species of swans breeding regularly in North America; the common Tundra Swan (*Cygnus columbianus*), seen in Saskatchewan during migration to and from the Arctic, and the much larger Trumpeter Swan (*Cygnus buccinator*) that at one time nested throughout western Canada. The Mute Swan (*Cygnus olor*), first introduced as a park species from Eurasia, is now well established widely in the United States and in the Great Lakes area of Canada (Nelson 1980). In 1986, the Committee on the Status of Endangered Wildlife in Canada listed the Trumpeter Swan as a vulnerable species. According to the committee, animals listed as vulnerable exist in low numbers or in very restricted areas in Canada but are not threatened with immediate extinction due to the action of man. In Saskatchewan, the Trumpeter Swan is listed as endangered (a species threatened with imminent extinction or extirpation throughout all or a significant portion of its Saskatchewan range).

In the 19th century, the Trumpeter Swan nested throughout most of what is now Saskatchewan, but numbers dropped precipitously with over-harvesting: between 1821 and 1841, 16655 swan skins were taken from the English (Churchill) River district, 22491 from the Swan River district and 2382 from Cumberland House, most of these being Trumpeter Swans. In 1837 alone, over 100 000 swans and geese from the Hudson's Bay Territory were sacrificed for their quills (Houston et al. 1997). In most areas of western North America, the few remaining Trumpeters were shot and their eggs, when available, taken for food, before all but the earliest settlers appeared.

With the interest in conservation during 1910-1930, Trumpeter Swan numbers began recovering; numbers have now improved significantly with a continental population estimated at 20000. The west-coast population (discovered in 1954) numbers about 15000. Another 2500 winter in the Tri-state (Montana, Idaho and Wyoming) area and about 1400 of those spend the summer in Alberta, Yukon and the Northwest Territories. There are 400 birds in the eastern half of the continent and about 600 birds are captive. At the current annual population growth rate of 8 to 10 per cent, the Canadian population will be between 1500 to 2300 by the year 2000, meeting population objectives outlined in the North American Waterfowl Management Plan (Greenwood and Young 1987). Caithamer (1996) also reports 1400 Trumpeter Swans in the Great Lake regions.

One critical factor limiting the Trumpeter Swan population in western Canada may be the lack of winter habitat in the northwestern United States. In most cases, the known winter areas are overcrowded which results in swans starving during harsh winters.

Until recently, the only known Trumpeter Swans in Saskatchewan were in the Cypress Hills (southwestern Saskatchewan) but this population has fallen dramatically. In 1971 and 1972 three breeding pairs produced 9 and 10 cygnets, respectively. From 1983 through 1988, only a single pair was present; the nest and eggs were abandoned in 1986, two cygnets were produced in 1987, and no eggs were seen in 1988 (Killaby 1991). Recent records indicate that in 1989 one pair and one cygnet were seen, in 1990 one pair and two cygnets, in 1991 one pair and one cygnet, in 1992 through 1995 one adult each year.

With the discovery of Trumpeter Swans in the Greenwater Park - Porcupine Provincial Forest area, surveys were undertaken to determine the status of this population and look at the possibility of enhancement. Enhancement would be of high priority if the Greenwater-Porcupine population wintered in areas that were not overcrowded (non-traditional wintering areas).

Methods

Beginning in 1990, aerial surveys were flown in the Greenwater Park and Porcupine Forest to document the presence of Trumpeter Swans. With the discovery of additional swans in the Porcupine Forest during routine air patrols used for fire protection, a major portion of the Porcupine Forest was added to the yearly monitoring program. To determine where the swans were wintering, a marking program was undertaken.

Flights were organized (if a plane was available) during early June and the first part of September. Flying in June gave information on nesting success and September information revealed summer survival of cygnets and the expected number of swans that would migrate. Adult swans were captured in July using a power boat and large dip net. After the swans were captured, they were fitted with a plastic neck collar utilizing the colour, letter and number combinations as required by Canadian Wildlife Service, along with a leg band. No attempt was made to band cygnets due to the possible stress during handling.

Trumpeter Swans in the Greenwater Park - Porcupine Forest Area

Since 1986, Trumpeter Swans have been documented in the east central region of Saskatchewan in a landscape area known as the Porcupine Hills in the Mid-Boreal Upland ecoregion of the Boreal Plan ecozone. This ecoregion is represented by areas of aspen (*Populus tremuloides*) forest with smaller mixed wood areas of White Spruce (*Picea glauca*) and aspen and includes many small lakes and pond and associated aquatic vegetation suppling idea habitat for Trumpeter Swans. The Porcupine Hills landscape area includes Greenwater Provincial Parks and the hills which run from the park east into Manitoba.

A pair of swans was first observed by local residents in Greenwater Park during the summer of 1986, and it is assumed that it was this pair that was seen in 1987 and 1988 (Trumpeter Swans return to the same site each summer). This pair was photographed in 1989 by Don Hooper, a local naturalist, and it was from these photos that the Royal Saskatchewan Museum in Regina and the Ornithology section of the National Museum in Ottawa were able to confirm that they were Trumpeter Swans and not the more common Tundra Swan. This pair was also observed a number of times by Hooper and park staff during the summer of 1990 (Hooper 1991).

During the early summer of 1991, the Greenwater pair was observed with one cygnet and a nesting site was located on a beaver pond north of Greenwater Lake. On 23 July, this pair was captured, leg and neck bands attached and blood sampled. The cygnet

TABLE 1. Survey information for Greenwater/Porcupine area between summer of 1990 and summer of 1995.

Site # & Location	1990	1991		1992		1993		1994		1995
	June	19 June	23 June	10 June	11 Sept.	28 May	23 Aug	22 June	1 Sept.	24 July
1. Sec 17-Tp41-R11-W2	2A	2A-1C	2A	1A seen by the general public		1A		2A		1A
2. Sec 7-Tp42-R1-W2				2A-4C	2A-3C	2A	2A	2A-3C	2A-5C	2A
3. Sec 36-Tp39-R4-W2						2A-2C (23 June)	2A	2A	2A	
4. Sec 7-Tp38-R2-W2						2A (8 June)	2A-1C	1A	3A	2A
5. Sec 25-Tp37-R3-W2				2A	2A				2A	
6. Sec 25-Tp37-R3-W2						2A	2A-1C	2A	2A-2C	
7. Sec 20-Tp38-R7-W2						2A 2A	2A 2A	3A 1A	2A	
8. Sec 15-Tp39-R9-W2				2A-4C	2A-4C	2A	2A-2C	2A-2C	2A-3C	2A
9. Sec 18-Tp40-R8-W2						2A 1A	1A 2A	2A	2A	2A
10. Sec 4-Tp39-R8-W2						2A		2A-2C		
11. Sec 4-Tp46-R9-W2								3A	3A	1A
12. Sec 20-Tp41-R8-W2						2A				
13. Sec 18-Tp38-R2-W2										3A
14. Sec 3-Tp40-R4-W2										3A
15. Sec 13-Tp39-R6-W2										1A
16. Sec 4-Tp39-R6-W2										2A-5C 11 August
17. Sec 11-Tp49-R19-W2										2A 1 July
Total	2A	2A-1C	2A	7A-8C	7A-7C	22A-2C	17A-4C	22A-7C	20A-10C	21A-5C

A = adult C = cygnet

was no longer with the pair. Blood tests revealed that the female had a kidney problem. In October, this pair was seen at LaCreek National Wildlife Refuge near Martin, South Dakota. During the spring of 1993 and to date, only the male has been observed in the Greenwater area; the female is believed to have died of kidney failure at LaCreek or during spring migration.

Table 1 indicates the location of Trumpeter Swans 1990-1995 found each year. To use this information for population trends might be premature. The difference in between populations in 1992 and 1995 could to some extent because we learned in what type of habitat to look for swans so that more of this habitat was flown each year. (Surveys were done in somewhat of a random casual fashion but concentrated in areas where the habitat appeared suitable for swans). Once we started working with the swans and placing articles in newspapers, local people indicated swans to us known to them in parts of the Porcupine Forest since 1985.

Table 1 and Figure 1 also indicate possible range extensions. In 1994, three adult Trumpeter Swans were found on the edge of the Northern Provincial Forest about 40 km north from the swans in the Porcupine Forest (site #11) and in 1995 two adults were found about 90 km northwest of the swans in the Porcupine Forest (site #17).

Considering the ratio of cygnets to adults in 1992-1995, inclusive, there was a poor hatch or low cygnet survival in 1993 and 1995 (Table 1). G. Beyersbergen, Canadian Wildlife Service, reported in 1993 a similar finding for Alberta and suggested it was likely due to a very cool wet spring in 1993. The low number of cygnets in 1995 was probably related to other factors than spring weather as the spring was dry and warm.

All seven adult swans banded in 1994 and the male of the pair banded in 1991 were seen in October 1994 at LaCreek National Wildlife Refuge in South Dakota. In December of 1995, five of the seven swans banded in 1994 and the male of the pair banded in 1991 were seen at LaCreek. The two banded swans not seen at LaCreek in December 1995 were probably observed at the capture site during the summer of 1995. (During the 1995 survey, swans were seen at most of the capture sites but bands were difficult to observe). It would appear that the LaCreek population has expanded into the Porcupine Forest - Greenwater area. Based on what nesting habitat the swans appear to be using in Saskatchewan and a very crude inventory of existing habitat, it would appear that only a small portion of the breeding habitat is currently being used. The overcrowded situation at LaCreek wintering area could prevent more expansion of the nesting populations in Saskatchewan.

The resident and summer migrant population at the LaCreek National Wildlife Refuge originated from birds transplanted from the Tri-states. During the summer, LaCreek swans nest in South Dakota, Nebraska, Wyoming and Saskatchewan. With about 225 swans wintering at LaCreek, overcrowding during harsh winters is now a problem. Some swans leave the refuge in search of open water and this demonstrates that Trumpeter Swans may search for additional wintering areas (Kraft 1990). Rolf Kraft, Refuge Manager at LaCreek, sums up the concerns of

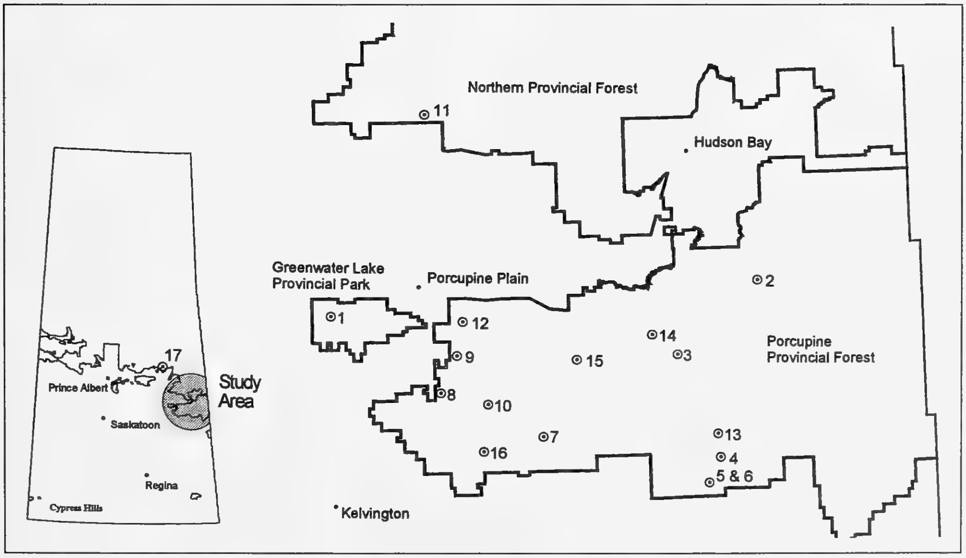

FIGURE 1. Location of Trumpeter Swans, Porcupine Provincial Forest, Saskatchewan.

the United States Fish and Wildlife Service on wintering swans in the northwestern United States in the following statements: "There is no doubt that considerable winter pioneering and some migration is taking place, but the loss in birds, though undocumented, must be significant (talking about the LaCreek Refuge). We as a profession restored these magnificent birds to their former breeding ranges without adequate consideration for their winter survival. It is now incumbent upon us to find suitable wintering habitat and assist this species to find it" (Kraft 1990).

A decision to enhance the Trumpeter Swan population in Saskatchewan through such management techniques as transplants cannot be made without consideration of availability of winter habitat. The long term decisions regarding management of Trumpeter Swans must be shared between the Canadian Wildlife Service, the United States Fish and Wildlife Service and the Wildlife agencies in the province and states where the swans currently nest, winter, and could potentially winter. Trumpeter Swans should be managed to add and restore biodiversity.

Acknowledgements

The work with the Trumpeter Swans is dedicated to the late Donald Hooper of Somme, Saskatchewan. He was the first to recognize that Trumpeter Swans existed in Greenwater Park and encouraged department staff to investigate the possibility of a breeding population of Trumpeter Swans throughout the Porcupine Forest. MacMillan Bloedel, Hudson Bay, provided financial assistance during the project. Special thanks are extended to Bob Brooks, Woodlands Manager with MacMillan Bloedel. Bob's interest in wildlife was instrumental in the success of the study. The World Wildlife Fund provided funding from the Endangered Species Recovery Fund. Len Shandruk and Gerard Beyersbergen of Canadian Wildlife Service, helped with handling and provided advice regarding Trumpeter Swan management. Nature Saskatchewan provided funding and support through out the study. Dave Duncan and Rick Bates, Saskatchewan Wetland Conservation Corporation, assisted throughout the study. Rolf Kraft and staff at the LaCreek National Wildlife Refuge supported the study, including six years of monitoring swans from Saskatchewan on the winter area. Bob Derksen with Athabaska Airways is thanked for his skill as a helicopter pilot and Leo Hiebert for not only flying the fixed wing for the surveys but for his interest in swans which resulted in finding swans during routine forest fire patrols. Without the assistance and personal interest in Trumpeter Swans of Ross Duncan and field staff in the Prince Albert Region, the study would not have been possible. Stuart Houston, Wayne Harris, John Mulhern, and Dwight Dobson contributed critical comments.

Documents Cited

Greenwood, H., and **A. Young.** 1987. Unpublished report prepared for Saskatchewan Natural History Society, Regina. Phase I of a Study on the Restoration of the Trumpeter Swan Population in Saskatchewan. Historical Range, Exploitation and Population Trends 1743–1987.

Kraft, R. 1990. Unpublished report. Status Report of the LaCreek Trumpeter Swan Flock for 1990. U.S. Fish and Wildlife Service, LaCreek National Wildlife Refuge, Martin, South Dakota.

Literature Cited

Caithamer, D. 1996. 1995 Survey of Trumpeter Swans in North America. U.S. Fish and Wildlife Service. 14 pages.

Hooper, D. F. 1991. Trumpeter Swans in eastern Saskatchewan. Blue Jay 49: 72–74.

Houston, C. S., M. I. Houston, and **H. M. Reeves.** 1997. The 19^{th} century trade in swan skins and quills. Blue Jay 55: 24–34.

Killaby, D. 1991. History and status of Saskatchewan Trumpeter Swans. Page 211 *in* Proceedings of the second endangered species and Prairie Conservation Workshop. *Edited by* G. L. Holroyd, G. Burns, and H. C. Smith. Regina, January 1989. Provincial Museum of Alberta Occasional Publication 15.

Nelson, H. K. 1980. Mute Swan population distribution and management in the United States and Canada. North American Swan. Bulletin of the Trumpeter Swan Society. Pages 14–15.

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Observations of Sowerby's Beaked Whales, *Mesoplodon bidens*, in the Gully, Nova Scotia

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Little is known about most members of the family Ziphiidae, the beaked whales. Sowerby's Beaked Whale (*Mesoplodon bidens*) is known from only a handful of sightings and strandings; few descriptions of group composition or surfacing behaviour are available. During 1997 and 1998, groups of Sowerby's Beaked Whales were observed in the Gully, a submarine canyon off eastern Canada, on four occasions. Sightings were in water depths of between 550 and 1500 m. Group size varied from 3 to 8-10 individuals. A mixed composition group was observed on one occasion, consisting of at least two female-calf pairs and two to four adult males (based on the presence of visible teeth and extensive scarring). Another group consisted of three quite heavily-scarred and therefore presumably male animals. Whales were observed to dive for between 12 and 28 minutes. Blows were either invisible or relatively inconspicuous. During all surfacings the long beak projected from the water well before the rest of the head or back was visible. While surfacing behaviour was generally unremarkable, one individual tail-slapped repeatedly.

Key Words: Sowerby's Beaked Whale, *Mesoplodon bidens*, Ziphiidae, surfacing behaviour, group composition, Nova Scotia.

Beaked whales (family Ziphiidae) are notoriously difficult to observe and identify at sea (International Whaling Commission 1989; Mead 1989), due to their tendency to live in deep (and thus, usually, offshore) waters, to dive for long periods of time, and because of similarities in appearance between species. Seven species of beaked whales have been recorded in the North Atlantic (Jefferson et al. 1993). The Northern Bottlenose Whale (*Hyperoodon ampullatus*) is probably the best known of these, primarily due to recent at-sea studies in the Gully, a submarine canyon off the coast of Nova Scotia (Whitehead et al. 1997a; b). Other North Atlantic beaked whales include Cuvier's Beaked Whale (*Ziphius cavirostris*) and the Mesoplodonts: Blainville's Beaked Whale (or Dense-beaked Whale, *Mesoplodon densirostris*), Sowerby's Beaked Whale (*Mesoplodon bidens*), True's Beaked Whale (*Mesoplodon mirus*), Gervais' Beaked Whale (*Mesoplodon europaeus*), and Gray's Beaked Whale (*Mesoplodon grayi*) (International Whaling Commission 1989; Jefferson et al. 1993). Like other species in the genus *Mesoplodon*, most of what is known about Sowerby's Beaked Whales comes from stranded individuals and a few scattered sightings, and relatively little is known about group composition or even details of surface behaviour (Sergeant and Fisher 1957; Lien et al. 1990; Ostrom et al. 1993). The group composition and behaviour of Sowerby's Beaked Whales sighted during two research trips studying Northern Bottlenose Whales in the Gully, a submarine canyon off Eastern Canada (Figure 1), are described here.

Methods

Observations were made by the authors and by several observers from a 13 m diesel-powered auxiliary yacht, which was under power throughout the observation periods. Sowerby's Beaked Whales were sighted and positively identified on four occasions (Table 1). During the first encounter in 1997 and both encounters in 1998, no other cetaceans were present in the area, but the second sighting in 1997 was of Sowerby's Beaked Whales within 300 m of a group of three Northern Bottlenose Whales.

During the first encounter in 1997 (08:51, 8 July), a total of 87 photographic frames were taken (51 colour, 36 black-and-white). None were taken during the second sighting (18:40, 8 July) but observed field

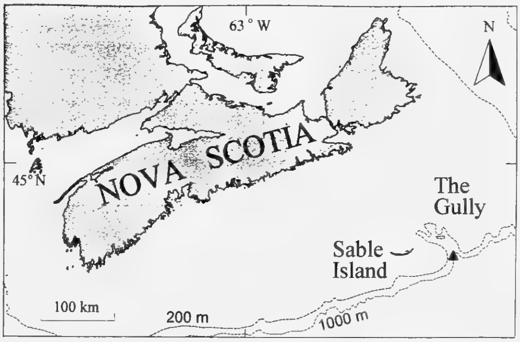

FIGURE 1. Map showing location of the Gully relative to mainland Nova Scotia (▲ denotes area of sightings).

TABLE 1. Sightings of Sowerby's Beaked Whales in the Gully, Nova Scotia.

Date	Time (W)	Position	Group Size	Depth (m)
8 July 1997	08:51 – 10:18	43°49.4' N; 58°57.6' W	8-10	1000
8 July 1997	18:40 – 18:46	43°54.6' N; 58°59.1' W	at least 3	1500
17 August 1998	11:06 – 11:58	43°45.9' N; 58°57.4' W	3	1250
20 August 1998	16:22 – 16:24	43°50.5' N; 58°59.4' W	4-5	550

characteristics were identical to those during the earlier encounter. Whales were tentatively identified in the field as *Mesoplodon bidens* and later confirmed from the photographs taken, which showed the long and uniformly grey beak (Figure 2; Jefferson et al. 1993). The whales were first sighted approximately 1000 m away, from the crow's nest vantage point (10 m up the mast). Their blows were relatively inconspicuous; the primary sighting cue was the silhouettes of the whales' backs in the fairly calm sea conditions (light winds, 30 cm sea swell and 15 cm chop). Sighting conditions were overcast (90% cloud cover) with good visibility. Sea surface temperature was 12.1°C; air temperature was 16.5°C.

In 1998, a total of 71 photographic frames (14 colour, 57 black-and-white) were taken during the first encounter (17 August), while only 8 frames (all black-and-white) were taken during the second encounter (20 August). Sighting characteristics of the first encounter were similar to those in 1997: whales were first seen 700 m away in calm sea conditions (light winds, 40 cm swell and 15 cm chop) with an overcast sky and good visibility. The second encounter was in slightly heavier sea conditions (1 m swell and 10 cm chop with 60% cloud cover). Whales were first observed only 200 – 300 m from the research vessel but dove as the vessel approached to within 50 m and were not seen again. Sea surface temperature for both sightings in 1998 was 20.5°C; air temperature was 22°C.

Observations

Sightings varied in depth from 550 to 1500 m (Table 1). Sightings were all in the same general location (within a 16 km by 3 km area) on the southwest edge of the Gully submarine canyon (Figure 1). During all encounters, animals usually surfaced within a couple of body lengths from each other, breathing within 4 to 5 seconds of each other (Figure 2a). The surfacing appearance of these whales was very different to that of Northern Bottlenose Whales. On surfacing, the beak appeared first, at an angle of 30-45° to the water surface, then dipped into the water just before the animals exhaled and the slate-grey back and dorsal fin appeared. Carlström et al. (1997) describe similar surfacing behaviour for two *Mesoplodon bidens* observed in the Norwegian Sea.

During the first encounter (8 July 1997), a total of 8-10 whales were present. The presence of so many individuals prevented reliable estimation of dive times. However, all animals were submerged between 09:22 and 09:50, so individual dives were a minimum of 28 min. For the majority of the sighting, individuals appeared to be milling in the same general area, although they moved continuously at 1 to 2 knots at the surface. At 10:05, one whale tail-slapped a number of times.

Sizes of whales observed were estimated as ranging from 2 - 4.5 m. Based on the relative size of individuals (noted both in the field and from photographs, Figure 2b), at least two calves were present, each associating with different adult-sized animals. From examination of photographs, two individuals were positively identified as adult males (Figure 2c), with erupted teeth visible (Lien and Barry 1990). Four whales (including the two known males) showed long linear scars on their backs and sides. Such scarring has previously been documented solely on adult males (Heyning 1984; MacLeod 1998). Neither of the adults associated with calves had such scars. On the basis of this, at least four adult males, two adult females and two calves were present. One of the known males was missing a large chunk out of the top of its dorsal fin (Figure 2d).

During the third encounter (17 August 1998), three individuals were present. The sizes of these animals were estimated in the field as approximately 4.5 m. Photographs taken showed a fairly substantial amount of linear scarring on all three individuals, which were therefore probably males (Heyning 1984; MacLeod 1998). During the encounter, four surfacing bouts were observed. Surfacing bouts were generally 1-2 min duration, during which time the animals would surface 6 to 8 times. The whales appeared to have no fixed direction of travel during surfacing bouts and would change direction up to 180° between surfacings. The dive times between these surfacing bouts were 14 min, 14 min and 12 min. The horizontal distance travelled during two of these dives was measured (using the research vessel's GPS) as 600 m and 750 m. The final surfacing bout was 7 min long, after which the whales were not observed again.

The last encounter (20 August 1998) was estimated in the field to be of a group of 3-4 animals of approximately 4 - 4.5 m length and one calf of 2.5 – 3 m length. Photographs taken during this encounter showed that at least one animal in this group had a

FIGURE 2. Sowerby's Beaked Whales seen in the Gully, 8 July 1997: (a) typical surfacing appearance; (b) female and calf (right); (c) two adult males (foreground), erupted while tip of tooth visible (under magnification) in the centre of each jaw; (d) adult male with M-shaped dorsal fin. Photographs (a) (c) and (d) by R.W. Baird; (b) by B. Müller.

small amount of linear scarring, while the adult-calf pair had no visible scarring.

Discussion

The group of 8-10 individuals observed on 7 July 1997 is larger than has been documented for any of the strandings (up to 6 individuals, Lien et al. 1990) or sightings (up to 5 individuals, Marion et al. 1988) in the western North Atlantic. However, such large groups have been seen elsewhere in the North Atlantic. A group of 8-10 individuals was sighted northeast of the Shetland Islands (Benjaminsen et al. 1976; Christensen 1977) and a group of about ten individuals was sighted in the Norwegian Sea (Øynes 1974). The confirmed mixed-sex composition of this group (and the probable mixed sex composition of the group observed on 20 August 1998) contradict suggestions that *Mesoplodon bidens* groups may be segregated by size, age or sex (Lien et al. 1990). However, since we could not confirm the presence of immature animals, we cannot refute the possibility that these may form separate groups or that at times such larger groups may separate. In fact, it is likely that the group of three animals seen on 17 August 1998 were all males. It is interesting to note that all reported records of sightings and strandings of Sowerby's Beaked Whales in the western North Atlantic have occurred between the months of July and October (Lien and Barry 1990). However, given the small sample size and likelihood of low observer effort (both at sea and monitoring strandings) during winter, this may be an artefact of effort.

The linear scarring observed on these animals (Figure 2d) is consistent with that shown by Heyning (1984), but appeared less extensive than that seen for some other *Mesoplodon* species. Heyning (1984) discusses the mechanism by which such scars are caused by intra-specific aggression between males. The presence of single linear rakes observed on Sowerby's Beaked Whales is consistent with this hypothesis, since the teeth of male Sowerby's Beaked Whales are located far back in the jaw, thus rendering it impossible to cause scarring with both teeth at once. However, it cannot be determined whether some of the scarring observed, particularly the missing dorsal fin tip (Figure 2d), could have been caused by another factor (possibly a shark, fishing gear or ship collision).

These encounters provide the first descriptions of at-sea behaviour of Sowerby's Beaked Whales in Canadian waters. There have only been six prior reports of this species in Canada (Lien and Barry 1990). Furthermore, there have previously been only three detailed reports of Sowerby's Beaked Whale sightings from the western North Atlantic, two of which were observed inshore in shallow water just prior to stranding (Dix et al. 1986; Lien et al. 1990), while the other was a sighting of three adults and two calves in the Hydrographer Canyon region, offshore of New Jersey (Marion et al. 1988). The lack of time spent at the surface by these whales, their fairly inconspicuous blows, and their distribution in offshore waters, are all probably responsible for the paucity of sightings. In the Gully, over 1800 hours of effort have been spent searching for whales (Hooker et al. *in press*) and these were the first confirmed identifications of Sowerby's Beaked Whales, although unidentified *Mesoplodon* species have been seen at least four times (H. Whitehead, personal communication). By comparison, Northern Bottlenose Whales are seen in the Gully at least daily (weather permitting), and on some days numerous times, so it is clear that despite the difficulties in observing Sowerby's Beaked Whales at sea, they should be considered quite uncommon in the Gully area.

Acknowledgments

Many thanks to Bob Pitman who looked at some of the slides and confirmed their identification as Sowerby's Beaked Whales. These sightings took place during research on Northern Bottlenose Whales in the Gully by Hal Whitehead's Research Group, Dalhousie University. Funding for this work is provided by a variety of sources, including the Natural Sciences and Engineering Research Council of Canada (NSERC), the Whale and Dolphin Conservation Society, World Wildlife Fund Canada, and the Canadian Federation of Humane Societies. Many thanks to crew members who participated in the research, particularly B. Carter and A. Gorgone. SKH was supported by a Canadian Commonwealth Scholarship, and RWB was supported by an NSERC post-doctoral fellowship. The manuscript benefitted from comments by J. Christal, S. Gowans, H. Whitehead, and two anonymous reviewers.

Literature Cited

Benjaminsen, T., J. Berlund, D. Christensen, I. Christensen, I. Huse, and **O. Sandnes.** 1976. Marking, sightings and behaviour studies of whales in the Barents Sea and at Svalbard in 1974 and 1975. Fisken og Havet 76: 9–23.

Carlström, J., J. Denkinger, P. Feddersen, and **N. Øien.** 1997. Record of a new northern range of Sowerby's beaked whale (*Mesoplodon bidens*). Polar Biology 17: 459–461.

Christensen, I. 1977. Observations of whales in the North Atlantic. Reports of the International Whaling Commission 27: 388–399.

Dix, L., J. Lien, and **D. E. Sergeant.** 1986. A North Sea beaked whale, *Mesoplodon bidens*, in Conception Bay, Newfoundland. Canadian Field-Naturalist 100: 389–391.

Heyning, J. E. 1984. Functional morphology involved in intraspecific fighting of the beaked whale, *Mesoplodon carlhubbsi*. Canadian Journal of Zoology 62: 1645–1654.

Hooker, S. K., H. Whitehead, and **S. Gowans.** *in press*. Marine protected area design and the spatial and temporal distribution of cetaceans in a submarine canyon. Conservation Biology.

International Whaling Commission. 1989. Report of the sub-committee on small cetaceans. Reports of the International Whaling Commission 39: 117–129.

Jefferson, T. A., S. Leatherwood, and **M. A. Webber.** 1993. Marine mammals of the world. United Nations Environment Program, FAO, Rome. 320 pages.

Lien, J., and **F. Barry.** 1990. Status of Sowerby's beaked whale, *Mesoplodon bidens*, in Canada. Canadian Field-Naturalist 104: 125–130.

Lien, J., F. Barry, K. Breeck, and **U. Zuschlag.** 1990. Multiple strandings of Sowerby's beaked whales, *Mesoplodon bidens*, in Newfoundland. Canadian Field-Naturalist 104: 414–420.

MacLeod, C. D. 1998. Intraspecific scarring in odontocete cetaceans: an indicator of male 'quality' in aggressive social interactions? Journal of Zoology, London 244: 71–77.

Marion, S., S. Frohock, and **P. Fontaine.** 1988. First sighting of *Mesoplodon bidens* in North American waters. NAMMA (North American Marine Mammal Association) News 9: 9–10.

Mead, J. G. 1989. Beaked whales of the genus *Mesoplodon*. Pages 349-430 *in* Handbook of marine mammals. *Edited by* S. H. Ridgway and R. Harrison. Academic Press, London.

Ostrom, P. H., J. Lien, and **S. A. Macko.** 1993. Evaluation of the diet of Sowerby's beaked whale, *Mesoplodon bidens*, based on isotopic comparisons among northwestern Atlantic cetaceans. Canadian Journal of Zoology 71: 858–861.

Øynes, P. 1974. Observations of basking sharks and whales in the Norwegian Sea in May-June 1974. Fisherinaeringens Forsoksfond, Rapporter 4: 43–46.

Sergeant, D. E., and **H. D. Fisher.** 1957. The smaller Cetacea of eastern Canadian waters. Journal of the Fisheries Research Board of Canada 14: 83–115.

Whitehead, H., A. Faucher, S. Gowans, and **S. McCarrey.** 1997a. Status of the northern bottlenose whale, *Hyperoodon ampullatus*, in the Gully, Nova Scotia. Canadian Field-Naturalist 111: 287–292.

Whitehead, H., S. Gowans, A. Faucher, and **S. W. McCarrey.** 1997b. Population analysis of northern bottlenose whales in the Gully, Nova Scotia. Marine Mammal Science 13: 173–185.

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Notes

Unusual Nest of a feral Rock Dove, *Columba livia*

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Middleton, Alex L. A., and Graham Nancekivell. 1999. Unusual nest of a Rock Dove, *Columba livia*. Canadian Field-Naturalist 113(2): 278.

A nest of a feral Rock Dove (*Columba livia*) at Guelph, Ontario, built mainly of nails, was discovered November 1996.

Key Words: Rock Dove, *Columba livia*, unusual nest, nails.

In the fall of 1996, during the conversion of an old seed warehouse into the Youth Music Centre, north-east fringe of the downtown core, and on the west bank of the Speed River, in Guelph, Ontario, 43°33′N, 80°15′W, it was discovered that Rock Doves, or feral pigeons, *Columba livia*, had been using the interior of the building for nesting. Many nests were situated on top of walls between large beams that supported the roof. In mid-November 1996 when the nests and accumulated debris were removed prior to renovation, one unusual nest was discovered.

This nest was located at the north end of the building, on top of the outside wall and immediately below the original roof about 4.5 m above the second floor. Construction workers carefully removed the nest and placed it, more or less intact, in a large cardboard box. The nest was constructed almost entirely of old and new nails, presumably collected from the abundance of fallen or rejected nails present on the construction site, interspersed with a few pieces of straw, leaf petioles, pine twigs, some wood chips, small pieces of cardboard, pigeon droppings and feathers. The percent contribution of each material could not be determined with accuracy as the nest was kept intact as part of the University of Guelph collection. Based on a visual examination, however, the minimum quantities of nails, their size, and weight (g) were as follows: 1 × 4″ straight nail (15.1 g); 3 × 3.5″ screw nail (8.7 g); 34 × 2.5″ straight nail (3.3 g); 5 × 2.5″ screw nail (3.3 g); and 44 × 2.25″ straight nail (2.4 g). Unfortunately the nest dimensions had not been measured in situ but following collection it weighed 1.2 kg, had a diameter of 21.0 × 25.0 cm and height of 9.0 cm. A nest cup was not clearly defined.

Most pigeons build their nests from a wide variety of plant materials including small twigs, roots, pine needles, straw, and heavy grass stems, but metal and wire have occasionally been recorded as nest components (Cramp 1985; Johnston 1992; Johnston and Janiga 1995). As no records were found of nests being built mostly of metal objects, the Guelph record seems noteworthy.

Many pigeons (80% of nesting pairs) reuse their nests and add new materials at each nesting (Johnston and Janiga 1995). Some nests may become as high as 20 cm, 50 cm wide, with a cup depth of 8 cm, and may weigh > 2.0 kg (Johnston 1992). The dimensions and mass of the Guelph nest fall within the mid-range for feral pigeon nests which, combined with the accumulation of feathers and feces in it, suggest it had been used for a number of nestings. If so, it appears that the pigeons that built this nest continued to use nails as their main nesting material. Therefore, the use of nails was not a single chance occurrence but the pigeons in question had found them to be an effective nesting material. This further demonstrates the well-known behavioral adaptability of this species to human created environments (Johnston and Janiga 1995).

Acknowledgments

We thank John Pawlikowski of Guelph, Ontario, who brought this nest to our attention.

Literature Cited

Cramp, S. 1985. Handbook of the birds of Europe, the Middle East, and North Africa. Volume 4. Oxford University Press, Oxford, United Kingdom.

Johnston, R. F. 1992. Rock Dove. *In* The Birds of North America, Number 13. *Edited by* A. Poole, P. Stettenheim, and F. Gill. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Johnston, R. F., and **M. Janiga.** 1995. Feral Pigeons. Oxford University Press, New York, U.S.A. and Oxford, United Kingdom.

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Adultes de *Nematodirus helvetianus* (Trichostrongylina: Molineoidea) dans le diaphragme de Coyote, *Canis latrans*, du Bas St-Laurent et de Gaspésie, au Québec

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Durette-Desset, M. C., R. Claveau, L. Measures, et R. Isabel. 1999. Adultes de *Nematodirus helvetianus* (Trichostrongylina: Molineoidea) dans le diaphragme de Coyote, *Canis latrans,* du Bas St-Laurent et de Gaspésie, au Québec. Canadian Field-Naturalist 113(2): 279–281.

Des spécimens adultes d'un nématode parasite de l'estomac des ruminants domestiques, *Nematodirus helvetianus*, ont été trouvés dans le diaphragme de 13 sur 38 coyotes capturés dans des "ravages" (quartiers d'hiver) de cerfs de Virginie, *Odocoileus virginianus*, dans le Bas St-Laurent et la Gaspésie au Québec, Canada. L'ingestion de moutons hébergeant des larves du 3ème ou du 4ème stade paraît un processus d'infection plus vraisemblable que l'ingestion accidentelle de larves infectives libres présentes sur la végétation, ce qui est le mode de transmission habituel chez les moutons. Cependant un travail expérimental est nécessaire pour vérifier cette hypothèse.

Mots clés: Coyote, *Canis latrans*, diaphragme, *Nematodirus helvetianus,* Trichostrongylina, Molineoidea, Québec

Adult specimens of *Nematodirus helvetianus*, a parasitic nematode in the stomach of domestic ruminants, were found in the diaphragm of 13 of 38 coyotes (*Canis latrans*) collected in winter yards used by White-tailed Deer (*Odocoileus virginianus*), in the Lower St. Lawrence and Gaspé Peninsula of Québec, Canada. The ingestion of domestic sheep harbouring third- or fourth-stage larvae is likely how coyotes acquired infections rather than by accidental ingestion of free-living infective larvae on vegetation which is how this parasite is normally acquired by sheep. However, experimental work to verify this hypothesis is required.

Key Words: Coyote, *Canis latrans*, diaphragm, *Nematodirus helvetianus,* Trichostrongylina, Molineoidea, Quebec.

L'infection des vertébrés par les nématodes primitifs s'effectue par pénétration transcutanée des larves infectives libres, puis migration pulmonaire précédant la localisation définitive dans la lumière digestive. Chez les nématodes plus spécialisés, l'infection se fait par voie orale et la larve se trouve directement dans le tube digestif; la migration pulmonaire devient donc inutile. Chez de très nombreuses espèces cependant, il subsiste un tropisme migratoire atavique, comme si une période de maturation tissulaire était nécessaire au développement de la larve. La larve quitte donc le tube digestif et effectue un séjour plus ou moins prolongé dans les tissus (généralement dans la muqueuse intestinale) avant de revenir dans la lumière intestinale.

Il paraît vraisemblable que ces tropismes tissulaires sont à l'origine de cas de parasitisme aberrant dont les observations rapportées ci-dessous fournissent un exemple remarquable.

Méthodes

Trente-huit coyotes *(Canis latrans)* ont été piégés, du 23 octobre 1995 au 16 janvier 1996, dans des "ravages" (quartiers d'hiver) de cerfs de Virginie *(Odocoileus virginianus).* Ces "ravages" sont situés dans des régions du Bas St-Laurent et de la Gaspésie, au Québec (approximativement de 64°15′ à 69°00′ de longitude ouest et de 47°50′ à 49°15′ de latitude nord) (Figure 1).

Les carcasses ont été amenées au bureau du ministère de l'Environnement et de la Faune du Québec (MEF) pour y être congelées, mais, auparavant, ont été soumises aux aléas climatiques pendant des temps variables, ce qui explique l'état d'autolyse de la majorité de ces carcasses à la réception au laboratoire.

Les carcasses ont été transmises au Laboratoire de pathologie animale de Rimouski du ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec et mises à dégeler dans une chambre froide à 4°C le 26 janvier 1996. Elles ont été examinées pour des recherches écologiques les 29 et 30 janvier avec, en particulier, la détermination de l'âge des spécimens par les méthodes de Jean et coll. (1986) et de Mansfield (1991).

Une nécropsie sommaire a été faite à ce moment pour la recherche, entre autres, de *Dirofilaria immitis* et de *Trichinella spiralis*. A cette fin, 10 g de muscle de chaque carcasse ont été soumis à une digestion peptique acide selon les techniques habituelles.

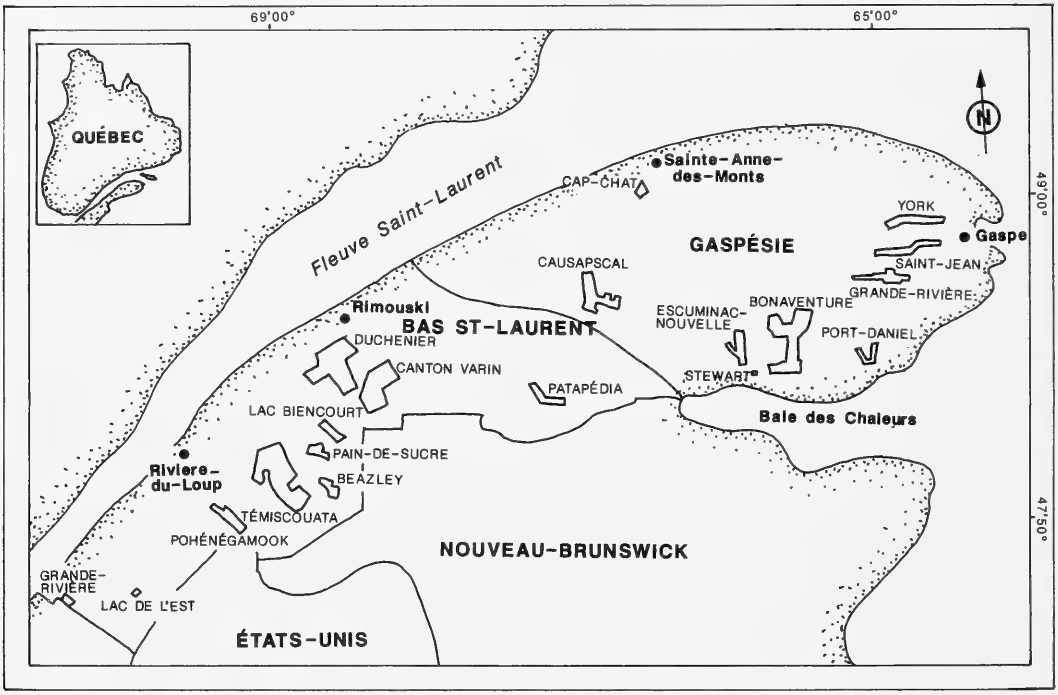

FIGURE 1. Localisation des "ravages" à cerf de Virginie où ont été piégés les coyotes.

Résultats

Les recherches de *Dirofilaria immitis* et de *Trichinella spiralis* ont été négatives.

Filaroides osleri a été observé chez 2 animaux à la bifurcation des bronches.

Chez de nombreux animaux (13 sur 38), de 1 à 10 spécimens environ de *Nematodirus helvetianus* May, 1920, ont été trouvés dans les muscles du diaphragme.

Le parasite est plus fréquent chez les coyotes âgés de 3.5 à 6.5 ans (4 positifs sur 7 examens) et les coyotes âgés de 1.5 à 2.5 ans (5 positifs sur 13) que chez les coyotes âgés de 6 mois (3 positifs sur 17). Un coyote (un mâle de 19.5 kg, âge inconnu) est infecté aussi.

La fréquence des animaux parasités paraît peu différente d'une station à l'autre: 2/13 à Témiscouata, 4/12 à Causapscal, 2/4 à la rivière York, 2/3 à Bonaventure, 1/3 à Cap-Chat, 1/1 à Biencourt, 0/1 à St-Jean et 1 coyote infecté d`un endroit inconnu (Figure 1).

Les parasites sont des vers adultes en mauvais état, mais parfaitement identifiables à *Nematodirus helvetianus* en raison de la forme très aigüe des lobes latéraux de la bourse caudale, du nombre de crêtes du synlophe (33 chez le mâle, 36 à 39 chez la femelle au milieu du corps) du nombre de denticules de la coronule (40 chez la femelle) et de la forme de la pointe des spicules (Figure 2).

L'appartenance de l'espèce à *N. odocoilei* Becklund et Walker, 1967, parasite habituel de cerf de Virginie, avait été envisagée car le coyote est un prédateur important de ce cerf dans certaines régions en Amérique du Nord, mais cette détermination peut être éliminée en raison, en particulier, de la forme de la bourse caudale.

Discussion

Nematodirus helvetianus est un parasite cosmopolite du bétail et, au Québec, aussi bien dans le Bas St-Laurent qu'en Gaspésie, il existe des élevages de vaches, de moutons et de chèvres. La biologie larvaire est comparable à celle des autres espèces de *Nematodirus* (cf Anderson 1992). Les 3ème et 4ème mues ont lieu respectivement 8 et 15 jours après l'infection. Les larves infectives libres peuvent se trouver dans la végétation très au-dessus du sol (Rose 1966) et il n'est pas impossible, *a priori,* que les coyotes puissent s'infecter en ingérant des larves infectives libres. Par ailleurs, Smith (1974) a noté, en octobre et novembre chez des veaux de l'est du Canada, l'existence de 4èmes stades larvaires "arrested". Ces formes en diapause pourraient donc également être à l'origine des infections des coyote. Cependant, il semble plus probable que le coyote, dont l'aire de répartition au Québec augmente depuis les années 1970 (Georges 1976), puisse être infecté par prédation d'animaux domestiques et particulièrement de moutons parasités par *N. helvetianus*. Une étude expérimentale est évidemment nécessaire pour vérifier ce hypothèse.

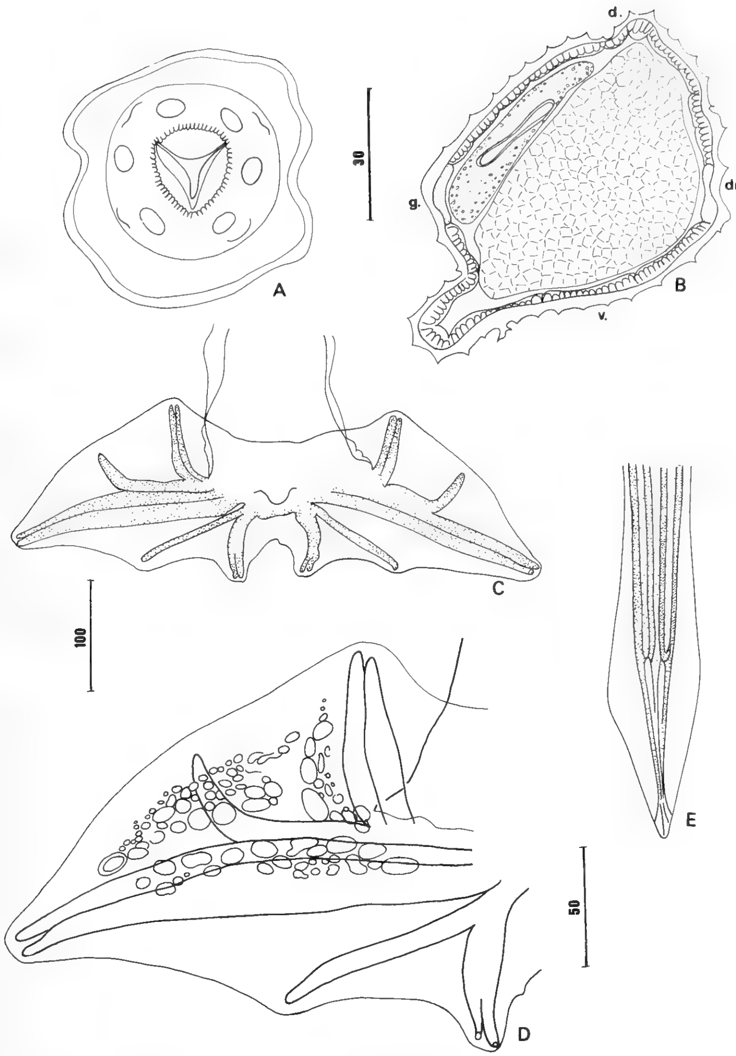

FIGURE 2. *Nematodirus helvetianus* du diaphragme de coyote. Femelle-A: tête en vue apicale; B: synlophe au milieu du corps. Mâle-C: bourse caudale, vue ventrale; D: détail de l'ornementation du lobe gauche de la bourse caudale, vue ventrale; E: pointe des spicules, vue ventrale. A, E, ech: 30 µm; B,D, ech: 50 µm; C, ech: 100 µm.

Littérature Citée

Anderson, R. C. 1992. Nematode parasites of vertebrates. Their development and transmission. C.A.B. International. University Press, Cambridge. xiii + 578 pages.

Georges, S. 1976. A range extension of the coyote in Quebec. Canadian Field-Naturalist 90: 78–79.

Jean, Y., J. M. Bergeron, S. Bisson, et **B. Larocque.** 1986. Relative age determination of coyotes, *Canis latrans*, from Southern Quebec. Canadian Field-Naturalist 100: 483–487.

Mansfield, A. W. 1991. Accuracy of age determination in the grey seal *Halichoerus grypus* of Eastern Canada. Marine Mammal Science 1: 41–49.

Rose, J. H. 1966. Investigations into the free-living phase of the life-cycle of *Nematodirus helvetianus.* Parasitology 56: 679–691.

Smith, H. J. 1974. Inhibited development of *Ostertagia ostertagi, Cooperia oncophora* and *Nematodirus helvetianus* in parasite-free calves grazing fall pastures. American Journal of Veterinary Research 35: 935–938.

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First Record of a Partial Leucistic Northern Ringneck Snake, *Diadophis punctatus edwardsi*, in Nova Scotia

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Gilhen, John. 1999. First record of a partial leucistic Northern Ringneck Snake, *Diadophis punctatus edwardsi*, in Nova Scotia. Canadian Field-Naturalist 113(2): 282–284.

On 28 June 1997, Jeremy J. Broussard found one partial leucistic adult male Northern Ringneck Snake, *Diadophis punctatus edwardsi*, approximately 300 millimetres in total length, upon turning over a rock in a boulder field at Geizer Hill, Halifax County, Nova Scotia (44°39′ 03″N, 63°39′ 28″W). This is the first record of a partial leucistic Northern Ringneck Snake in Nova Scotia.

Key Words: Northern Ringneck Snake, *Diadophis punctatus edwardsi*, partial leucistic, first record, Geizer Hill, Nova Scotia.

Jeremy J. Broussard and a friend, who enjoy catching snakes in their neighbourhood to observe and later release, were astonished to find a whitish Northern Ringneck Snake, *Diadophis punctatus edwardsi*, (Figure 1 and front cover). This adult male, approximately 300 millimetres in total length, was under a large rock in a one-half hectare bulldozed boulder field (Figure 2) at Geizer Hill, Halifax County, Nova Scotia (44°39′03″N, 63°39′28″W) during the afternoon of 28 June 1997. Jeremy has visited this site many times during the past three summers and commonly found four species of snake; Northern Redbelly Snake, *Storeria occipitomaculata occipitomaculata,* Maritime Garter Snake, *Thamnophis sirtalis pallidula,* Maritime Smooth Green Snake, *Liochlorophis vernalis borealis*, and Northern Ringneck Snake.

Jeremy brought this partial leucistic Northern Ringneck Snake to the Nova Scotia Museum of Natural History and it was photographed to preserve a colour record (Catalogue Numbers RE2425 - RE2448). This snake lacks black pigment. From a distance it appears to vary in colour from brownish-white on the trunk to greyish-white on the tail. Up close the skin between the scales on the back is dull white. The scales, however, are less glossy than normal and are translucent grey with a distinct orange-brown surface sheen. The top of the head is orange-brown with a dark brown patch that extends across the prefrontals. The neck-band and underside are paler orange than normal. The neck-band, which normally is bordered on both sides by a narrow black band, is bordered by translucent grey. The eyes appear to be normal but the tongue, which is typically brownish-black, is a uniform medium orange.

The Ringneck Snake, *Diadophis punctatus*, is wide-ranging in eastern and central North America and is represented by six subspecies: Southern Ringneck Snake, *D. p. punctatus* (southern New Jersey to Upper Florida Keys; west to the Appalachian Mountains in the South, and to southwestern Alabama); Key Ringneck Snake, *D. p. acricus*, (Big Pine Key, Florida); Mississippi, *D. p. stictogenys* (extreme southern Illinois to the Gulf of Mexico; western Alabama to eastern Texas); Prairie, *D. p. arnyi* (extreme southwestern Wisconsin and extreme southeastern South Dakota to south-central Texas and eastern New Mexico); Regal, *D. p. regalis* (west-central New Mexico to west-central Arizona and south to Durango and San Luis Potosi; disjunct populations from Idaho to southeastern California); and Northern, *D. p. edwardsi* (Nova Scotia to northeastern Minnesota; south through uplands to northern Georgia and northeastern Alabama; north in Mississippi Valley to Illinois; absent from large areas in Wisconsin, Illinois, Indiana and Ohio; isolated records in Indiana) (Conant and Collins 1998).

Albinism in this species was first reported for a Southern Ringneck Snake. Neill (1941) described a young individual, 140 millimetres in total length, found beneath a pile of dead grass in Augusta, Georgia, on 1 September 1939, as being pure white dorsally with a pearly iridescence, and behind the head was a ring of pale lemon-yellow. The ventral surface was light yellow, changing to a delicate rose pink on the underside of the tail, and there was a dark red spot in the centre of each ventral scute. The eyes and tongue were dark red. Neill stated, when held to the light the specimen was quite translucent. Hensley (1959) subsequently listed this specimen, adding Richmond County to the locality. Groves (1974) described an adult male measuring 224 mm in total length, collected in a field at Indian Mills, Burlington County, New Jersey, by Tim Marshall on 5 July 1974 , as pinkish-white dorsally, with an orange broken ring on its neck, 2½ scales wide at its widest point. The ventral surface was orange with a large half-moon shaped pink spot centrally located on most ventral scales. No spots were present on the caudal scales or on the chin and lower lips. The eyes and tongue were pink. Drykacz (1981) lists the third record, reported by John Lewis, as an albinistic indi-

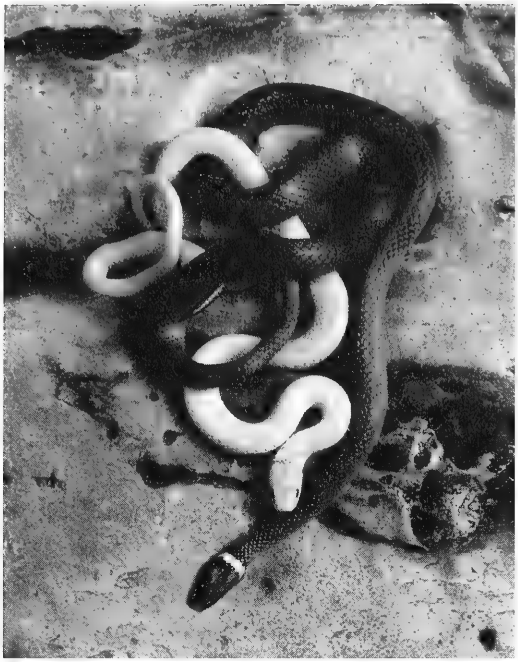

FIGURE 1. The partial leucistic adult male Northern Ringneck Snake, *Diadophis punctatus edwardsi*, from Geizer Hill, Halifax County, Nova Scotia, and a normally coloured individual. (Nova Scotia Museum of Natural History Slide Number RE2448).

Figure 2. Bulldozed boulder field at Geizer Hill, Halifax County, Nova Scotia, where a partial leucistic Northern Ringneck Snake, *Diadophis punctatus edwardsi*, was collected. (Nova Scotia Museum of Natural History Negative Number 23628: Frame 11).

vidual which was found dead in a recently plowed field north of Clearwater, Pinellas County, Florida during the spring of 1978.

There is one record of albinism in the Prairie Ringneck Snake. Earle (1958) stated that a female albino ring-necked snake, *Diadophis punctatus arnyi*, 322 mm in total length was collected near Alma, Wabaunsee County, Kansas, in July 1957 and received by the Museum of the University of Colorado (UCM9861).

The first record of an albinistic Northern Ringneck Snake was reported by Cooper (1958). Cooper described an adult specimen found under a flat rock beside a rocky stream bed on the outskirts of Bayrd, West Virginia, by Glen Griffin on 29 May 1954 as being white with a yellowish ring around its neck. It was deposited in the collection of Charles J. Stine of Baltimore. Hensley (1959) and Bradshaw (1966) subsequently listed this record. Hensly added Anne Arundel County to the locality but Bradshaw suggests "Bayard, Grant County," West Virginia is the proper locality. Bradshaw (1966) recorded a juvenile 149 mm in total length, found in a wooded section along the rocky stream course of Falling Run, in Morgantown, Monongalia County, West Virginia in October 1965. He stated that the complete absence of melanin and other pigments was evident from the pink colour of the body, the iris of the eye, and the tongue. Only the ring at the base of the head suggested pigmentation and was faintly distinguishable from the rest of the dorsal scalation by a pale yellowish cast. Measurements and scale counts are provided from the dried specimen. The third record, reported by Bryant (1974) and subsequently by Drykacz (1981), was collected near Camp Bradford, Martinsville, Morgan County, Indiana on 5 October 1974. It is described as a partially albinistic adult with a normal neck ring and a yellowish belly.

The adult male partial leucistic Northern Ringneck Snake collected at Geizer Hill, Nova Scotia, is the only record of albinism for this subspecies in Nova Scotia and Canada and represents the fourth in its range in northeastern North America.

Drykacz (1981) provides a very useful table defining degrees of albinism. In order to try to standardize the description of albinistic specimens he adapted the criteria of Brame (1962), Peters (1964) and Harris (1970). He defines a complete albino as lacking all integumentary pigment including the eyes. A complete leucistic individual is lacking all integumentary pigment except the eyes are normal. Of the four descriptions of partial albino given in his table, two apply to *Diadophis punctatus*. An individual lacking all integumentary pigment except with yellow pigment is a partial albino with xanthophores and one with only red pigment is a partial albino with erythrophores. The Northern Ringneck Snake from Geizer Hill, having normal eye pigment with an orange neck ring, underside of trunk and tail, would be partial leucistic with erythrophores. Individuals having brassy flecking, or partial albino with iridophores, and with small scattered areas of normal pigmentation, or an albinistic pinto, have not been reported in the Ringneck Snake.

Naturalists and herpetologists have been reporting the occurrences of amphibians and reptiles in Nova Scotia for over 130 years, yet albinism was only first reported (in an Eastern Redback Salamander, *Plethodon cinereus*) in 1973 (Gilhen 1986). Odd colour morphs are more likely to be expressed in populations with increased inbreeding as a result of isolation in fragmented disturbed habitat, caused mostly by urban development. Therefore occurrences may serve to document the effects of increasing human impact. At Geiser Hill suitable habitat has been reduced to a boulder field with patches of old field vegetation, bounded on the north and west sides by young trees and shrubs adjacent to the Bicentennial Highway, south by back yards and homes along Dunbrack Street and east by homes along Main Avenue.

The grey slate and quartzite slopes along the west side of Bedford Basin are well known as Northern Ringneck Snake habitat. Reports of young individuals, in particular, getting inside houses and apartment buildings are not uncommon. Over the past 30 years, this area, from Geizer Hill northeast to the town of Bedford, with the exception of Mount St. Vincent University campus and a city park, Hemlock Ravine, has been developed into housing subdivisions and shopping plazas. However, between developments, there remains much fragmented habitat of mixed forest surrounded by bulldozed push-offs and rocky clearings which are in various stages of forest regeneration. At Rockingham Ridge, about 1 km west of Geiser Hill, two partial albino Green Frog, *Rana clamitans melanota*, tadpoles were observed in a pond in a rocky clearing on 13 May 1987.

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Literature Cited

Bradshaw, W. N. 1966. An albino Eastern Ringneck Snake, *Diadophis punctatus* (Linnaeus), from West Virginia. Proceedings of the West Virginia Academy of Science 38: 13–14.

Brame, A. H., Jr. 1962. A survey of albinism in salamanders. Abhandlungen und Berichte Naturkunde Vorgeschite 11: 65–81.

Bryant, J. 1974. An abnormally pigmented ringneck snake. The Kentucky Herpetologist 5 (10–12): 10.

Conant, R., and **J. T. Collins.** 1998. A field guide to reptiles and amphibians of eastern and central North America. Third Edition, Expanded. Houghton Mifflin Company. New York. 616 pages.

Cooper, J. E. 1958. Some albino reptiles and polydactylous frogs. Herpetologica 14: 55.

Drykacz, S. 1981. Recent instances of albinism in North American amphibians and reptiles. Society for the study of amphibians and reptiles. Herpetological Circular Number 11.

Earle, A. M. 1958. Albinism in the Prairie Ring-necked Snake. Herpetologica 13: 272

Gilhen, J. 1986. Two partial albino Eastern Redback Salamanders, *Plethodon cinereus,* in Nova Scotia. Canadian Field-Naturalist 100: 375.

Groves, John D. 1974. An albino Ringneck Snake, *Diadophis punctatus*, from New Jersey. Bulletin Maryland Herpetological Society 10: 102.

Harris, H. S. 1970. Abnormal pigmentation in Maryland amphibians and reptiles. Bulletin Maryland Herpetological Society 4: 79–80.

Hensley, M. 1959. Albinism in North American amphibians and reptiles. Publications of Museum, State University 1 Biological Series: 133–159.

Neill, Wilfred T. Jr. 1941. A case of albinism in *Diadophis p. punctatus*. Copeia 1941: 266.

Peters, J. S. 1964. Dictionary of herpetology. Hafner Publishing Co., New York. v+426 pages.

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Bumblebees, *Bombus* spp., Foraging on Red Oak, *Quercus rubra*, Acorn Galls in Southern Ontario

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Larson, Brendon M. H. 1999. Bumblebees, *Bombus* spp., foraging on Red Oak, *Quercus rubra*, acorn galls in southern Ontario. Canadian Field-Naturalist 113(2): 285–286.

Bumblebees and other aculeate Hymenoptera were observed collecting a secretion associated with galls of *Callirhytis operator* (Cynipidae) on acorns of Red Oak (*Quercus rubra*) at Lake Matchedash, Ontario, in August 1996. This is the first record of bumblebees collecting gall secretions, which may be a locally important sugar source during mast years.

Key Words: Bumblebees, *Bombus*, cynipid wasp, *Callirhytis operator*, Cynipidae, Hymenoptera, Red Oak, *Quercus rubra*, acorn, galls, Ontario.

The phytophagous larvae of many insects induce production of galls on their plant hosts (reviewed in Shorthouse and Rohfritsch 1992). This interaction has received much attention because it is often detrimental to the host (Collins et al. 1983; Crawley and Long 1995) and because the galls support a diverse community of parasitoid and inquiline insects (Wiebes-Rijks and Shorthouse 1992; Schönrogge et al. 1995). Here, I report new observations concerning an additional interaction supported by gall insects that has not been discussed in the recent literature.

During early August 1996, I observed bumblebees (*Bombus* spp.) and other aculeate Hymenoptera (Table 1) collecting a secretion associated with galls on acorns of Red Oak (*Quercus rubra*). The *Q. rubra* trees were located along the shore of Lake Matchedash (also called Long Lake), Simcoe County, Ontario (79°30′45″W, 44°47′00″N). The galls were yellow in colour and located on the outside of the acorn near its junction with the cup (Figure 1), and were identified as the pip galls of the agamic generation of the cynipid wasp *Callirhytis operator* (Weld 1922; Felt 1940). The foraging bees and wasps assiduously walked and flew around the acorns, probing the edges of the galls with their proboscides. A steady humming sound produced by the large numbers of Hymenoptera foraging on the galled trees indicated that the secretion, which was sweet to human taste, was quite attractive to them. The year 1996 was apparently a mast year for *Q. rubra* at Lake Matchedash, and galls were present on most acorns. During August 1997, however, acorns and galls were much less frequent, and foraging Hymenoptera were rarely seen.

A variety of galls secrete a sugary liquid that is attractive to foraging Hymenoptera, including various bees, wasps and ants (reviewed in Bequaert 1924), but this is the first record of secretions associated with the galls of *C. operator*. Foraging wasps and honeybees have also been observed collecting secretions from bacterially-induced twig lesions on Gambel's Oak (*Q. gambelii*) and twig galls of Bur Oak (*Q. macrocarpa*) in Colorado (Kevan et al. 1983 and Eckberg and Cranshaw 1994, respectively). Bumblebees are known to collect homopteran honeydew, but they have not previously been reported collecting gall secretions (Morse 1982).

These observations draw further attention to the diverse ecological interactions centered around galls.

FIGURE 1. *Bombus terricola* foraging on galls on Red Oak at Lake Matchedash, Simcoe County, Ontario.

TABLE 1. Species of aculeate Hymenoptera found foraging on *Q. rubra* acorns at Lake Matchedash, Ontario, during August 1996. Voucher specimens are located in the Royal Ontario Museum, Toronto.

Apidae:
Apis mellifera L.
Bombus affinis Cresson
Bombus bimaculatus Cresson
Bombus ternarius Say
Bombus terricola Kirby
Eumenidae:
Eumenidae sp.
Vespidae:
Dolichovespula maculata (L.)
Vespula vidua (Saussure)

Q. rubra trees produce mast every two to five years (Sander 1990), and in these years galls may be an important sugar source for bumblebees and other Hymenoptera. This suggestion is supported by the commonness of acorn galls produced by *Callirhytis* species, including *C. operator*, which were present in 39% of *Q. rubra* populations sampled in eastern North America and infested an average of 3.7% (SE = 1.2%) of the crop ($N = 92$ populations; data from Gibson 1982). The secretions may also provide nutrients that are uncommon in the nectar of co-occurring flowers, but further analysis would be required to explore this possibility.

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Literature Cited

Bequaert, J. 1924. Galls that secrete honeydew: A contribution to the problem as to whether galls are altruistic adaptations. Bulletin of the Brooklyn Entomological Society 19: 101–124.

Collins, M., M. J. Crawley, and **G. C. McGavin.** 1983. Survivorship of the sexual and agamic generations of *Andricus quercuscalicis* on *Quercus cerris* and *Q. robur*. Ecological Entomology 8: 133–138.

Crawley, M. J., and **C. R. Long.** 1995. Alternate bearing, predator satiation and seedling recruitment in *Quercus robur* L. Journal of Ecology 83: 683–696.

Eckberg, T. B., and **W. S. Cranshaw.** 1994. Occurrence of the Oak Rough Bulletgall Wasp, *Disholcaspis quercusmamma* (Walsh) (Hymenoptera: Cynipidae), as a street tree pest in Colorado. Journal of the Kansas Entomological Society 67: 290–293.

Felt, E. P. 1940. Plant galls and gall makers. Comstock Publishing, Ithaca, New York.

Gibson, L. P. 1982. Insects that damage Northern red oak acorns. USDA Forest Service, Northeastern Forest Experiment Station Research Paper NE-492.

Kevan, P. G., S. St. Helens, and **I. Baker.** 1983. Honeybees feeding from honeydew exudate of diseased Gambel's Oak in Colorado. Journal of Apicultural Research 22: 53–56.

Mani, M. S. 1964. Ecology of plant galls. W. Junk, The Hague, Netherlands.

Morse, D. H. 1982. Behavior and ecology of bumble bees. Pages 245–322 *in* Social Insects. Volume 3. *Edited by* H. R. Hermann. Academic Press, New York.

Sander, I. L. 1990. *Quercus rubra* L. Northern Red Oak. Pages 727–733 *in* Silvics of North America. Volume 2, Hardwoods. Technical coordinators R. M. Burns and B. H. Honkala. USDA Forest Service Agriculture Handbook 654, Washington, DC.

Schönrogge, K., G. N. Stone, and **M. J. Crawley.** 1995. Spatial and temporal variation in guild structure: Parasitoids and inquilines of *Andricus quercuscalicis* (Hymenoptera: Cynipidae) in its native and alien ranges. Oikos 72: 51–60.

Shorthouse, J. D., and **O. Rohfritsch.** *Editors*. 1992. Biology of insect-induced galls. Oxford University Press, New York.

Weld, L. H. 1922. Notes on American gallflies of the family Cynipidae producing galls on acorns, with descriptions of new species. Proceedings of the United States National Museum 61(19): 1–32.

Wiebes-Rijks, A. A., and **J. D. Shorthouse.** 1992. Ecological relationships of insects inhabiting cynipid galls. Pages 238–257 *in* Biology of insect-induced galls. *Edited by* J. D. Shorthouse and O. Rohfritsch. Oxford University Press, New York.

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Albino Leach's Storm-petrel, *Oceanodroma leucorhoa*, in Nova Scotia

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Oxley, Jonathan Russell Oxley. 1999. Albino Leach's Storm-petrel, *Oceanodroma leucorhoa*, in Nova Scotia. Canadian Field-Naturalist 113(2): 287–288.

A complete albino Leach's Storm-petrel, *Oceanodroma leucorhoa*, chick was discovered on Bon Portage Island, Nova Scotia. It appears to be the only known record of albinism in this species.

Key Words: Leach's Storm-petrel, *Oceanodroma leucorhoa*, albinism, Bon Portage Island.

On 21 August 1997 a 33 day-old (± 3 days) completely albino Leach's Storm-petrel, *Oceanodroma leucorhoa*, chick was discovered on Bon Portage Island, Nova Scotia. (43°28′ N, 65°45′ W). Leach's Storm-petrels are small burrow-nesting Procellariformes that rear a single chick each breeding season. (82.5% fledging success on Bon Portage Island during the 1997 breeding season, unpublished data, author) Normal chicks are hatched with dark blue-gray natal down which is eventually replaced with black juvenile plumage except for a white rump patch. This latter plumage is also found in the adult birds.

The albino chick was 1 of 146 petrel chicks studied in a colony estimated at 45 000 breeding pairs (unpublished data, author). All existing natal down was pure white and the legs, feet, and bill were flesh colored. The iris was deep red. These albinistic characteristics remained as juvenile plumage replaced original down. Color photographs were taken at 34 and 64 days of age (see Figures 1 and 2). I could find no literature regarding albino petrels and presume this to be the first record of its kind (C. E. Huntington, Bowdoin College Biology Department, Brunswick, Maine 04011 USA, personal communication).

On 23 August, the wing chord of the albino chick measured 76 mm and the tarsus length 23.9 mm. On 19 September the wing chord measured 156 mm and the tarsus length 24.1 mm. On 21 August the mean wing chord and tarsus lengths for other normally plumaged petrel chicks in the colony were ($\bar{x}$ = 55.15 mm, SD = 23.89, n = 103) and ($\bar{x}$ = 22.01 mm, SD = 3.97, n = 108) respectively. On 20 September, these measurements were repeated (Wing chord: ($\bar{x}$ = 133.3 mm, SD = 26.58, n = 60) (Tarsus length: ($\bar{x}$ = 24.81 mm, SD = 0.92, n = 60). The albino chick weighed 59 g on 24 August, 71 g on 29 August, and 62 g on 19 September. The culmen measured 13.5 mm and the central rectrices 31 mm on 23 August. On the morning of 24 August the chick exhibited a distended belly and was remarkably warmer to the touch than the day prior indicating that the chick had been fed the previous night and had not been abandoned by its parents at that developmental stage (35 days). Tufts of down, secondaries (2), and rectrices (1) as well as the eggshell (normal coloration) were collected and preserved for possible later genetic analysis. (Acadia University Museum). The albino chick fledged successfully on or about 20 September 1997.

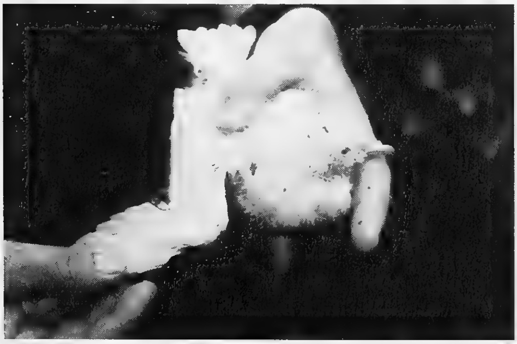

FIGURE 1. Albino Leach's Storm-petrel, *Oceanodroma leucorhoa*, at 34 days of age (± 3 days).

FIGURE 2. Albino Leach's Storm-petrel, *Oceanodroma leucorhoa*, at 64 days of age (± 3 days).

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American Dipper, *Cinclus mexicanus,* foraging on Pacific salmon, *Oncorhynchus* sp., eggs

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Obermeyer, Kim E., Angela Hodgson, and Mary F. Willson. 1999. American Dipper, *Cinclus mexicanus*, foraging on Pacific Salmon, *Oncorhynchus* sp., eggs. Canadian Field-Naturalist 113(2): 288–290.

We quantified the feeding rates of American Dippers (*Cinclus mexicanus)* foraging for salmon eggs and invertebrates along salmon rivers in southeastern Alaska. Dippers foraging in salmon-spawning stream reaches ate 1.8 eggs/minute versus 0.6 invertebrates/minute in non-spawning reaches. The success of dippers foraging for eggs, combined with high nutritional value of salmon eggs and their availability, may have consequences for dipper reproduction and populations.

Key Words: American Dipper, *Cinclus mexicanus*, Pacific Salmon, *Oncorhynchus*, predation, foraging, southeastern Alaska.

Pacific salmon (*Oncorhynchus* sp.) range along the Pacific coast of North America from California to Alaska, spawning inland to Idaho and the Yukon. During the spawning period, healthy salmon runs consist of thousands of fish and several species may choke streams from June to December. The range and intensity of salmon runs create the potential for strong ecological interactions through nutrient transfer from marine to freshwater and terrestrial systems (Willson et al. 1998), as well as direct consumption of spawning adult salmon, salmon carcasses, eggs, and rearing juveniles (Willson and Halupka 1995). Ecological interactions affect not only vertebrate predator/scavengers, such as Mink (*Mustela vison*; Ben-David et al. 1997), Brown Bear (*Ursus arctos*; Barnes 1989; Welch et al. 1997), and Bald Eagles (*Haliaeetus leucocephalus*; Stalmaster and Kaiser 1997), but also the aquatic biota (Wipfli et al. *in press*) and terrestrial vegetation (Bilby et al. 1996).

There have been few studies on the use of salmon eggs by wildlife (Willson and Halupka 1995). Fish eggs have been reported in dipper diets several times (Munro 1924; Ehinger 1930; Piorkowski 1995), but concentrated feeding on salmon eggs has been little reported. We observed American Dippers on several salmon streams along Lynn Canal in southeastern Alaska, documenting their utilization of salmon eggs.

Methods

We observed foraging dippers for approximately 15 hours at close range (< 50 m) along the Berners River using binoculars (Pentax 12x24) and recorded detailed notes on feeding behaviors. We measured with a hand-held stopwatch the time spent foraging and documented the type of prey (invertebrates or salmon eggs) consumed. Feeding rates were calculated as the number of prey items consumed per minute of foraging time. Dippers were observed from when they arrived at a stream reach until they left. We also observed dippers foraging on salmon eggs at Salmon Creek, Juneau, Alaska (58°30′N, 133°30′W), Berners River (40 miles northwest of Juneau; 58°55′N, 135°27′W), and Herman Creek, Haines, Alaska (59°30′N, 136°00′W).

Results and Discussion

On 10 July 1997, a family group consisting of one adult dipper with two fledglings was observed foraging on Salmon Creek. The group flew between gravel bars, where the adult entered Chum Salmon (*O. keta*) spawning redds, probing the substrate for shallowly buried eggs. The fledglings waited on shore for the adult to return with eggs, whereupon they begged for food. The adult collected seven eggs in four minutes. In July and August, 1998, we frequently observed dippers foraging on "drift eggs" (eggs not buried in redds) in several streams near Juneau.

On 17–23 October 1997, we observed multiple dippers (8–12 individuals) foraging for Coho Salmon (*O. kisutch*) eggs on the upper Berners River. Individuals were not marked, nor were they distinguishable except when viewed simultaneously. As before, dippers probed for shallowly buried eggs in the spawning redds. The average feeding rate for all dippers feeding on salmon eggs was 1.8 eggs/minute (23 bouts, 74 min.). For dippers feeding on invertebrates in non-spawning reaches, the feeding rate was 0.6 invertebrates/minute (12 bouts, 62 min.).

From early November to late December dippers were observed on Herman Creek. Coho Salmon were spawning in the stream during this time and dippers (3–5 individuals) were observed on several occasions foraging for eggs.

Dippers exhibited several foraging modes (*sensu* Kingery 1996) when searching for salmon eggs. Depending on water depth and availability of rocks to perch on, dippers used dive-plunging (jumping from rocks and diving to stream bottom), wade-plunging (wading and dipping head or head and body into stream), and swim-plunging (swimming on surface, then diving to bottom).

These observations show that American Dippers target and exploit salmon eggs as a food source from at least July to December in southeastern Alaska. Eggs may be available to dippers in stream gravel even after salmon have stopped spawning, thus extending the resource temporally. Given the geographic distributions of dippers and salmon, it is likely that the observed interaction is widespread where salmon populations are healthy. Salmon eggs provide a readily available, highly nutritious food source for dippers: Chum Salmon eggs contain about 3600J of energy, and the smaller eggs of Pink Salmon (*O. gorbuscha*) contain about 1420J (K. E. Obermeyer, unpublished data). In contrast, invertebrates from streams in this area contain an average of about 250J per prey item (K. E. Obermeyer, unpublished data); these values are similar to those reported in the literature (e.g., Cummins and Wuycheck 1971; Higgs et al. 1995). Thus foraging on salmon eggs clearly provided much higher levels of energy yield per item captured than foraging on invertebrates, as well as higher foraging rates.

Although dippers ate salmon eggs rapidly during foraging bouts, this rate is not sustained throughout the day; rapid intake rates permitted much time to be spent in non-foraging activities (e.g., preening and singing). It is unlikely that egg-foraging by dippers has a detrimental effect on healthy salmon populations (Munro 1924), because they are unable to reach eggs that are buried at normal depths of several centimenters and therefore only forage on eggs that probably would not survive anyway.

The availability of salmon eggs may influence dipper fledgling survival in late summer and fall and the body condition of birds preparing to overwinter. In addition, salmon carcasses increase the number of stream invertebrates and probably the biomass of young salmonids also (Bilby et al. 1996; Wipfli et al. 1998). Dippers feed on young fish as well as invertebrate prey (Munro 1924; R. H. Armstrong, personal communication; our 1998 observations). There exists a strong relationship between dipper abundance and their food (Ormerod et al. 1985). Furthermore, dipper fledgling survival is positively correlated with invertebrate availability (Price and Bock 1983), and nesting success may also be influenced by the abundance of food or body condition of the adults.

Future research should examine the effects of salmon on dipper biology and ecology including survival, reproduction, and seasonal movements. Many other species of birds, mammals, fish, insects, and vegetation are influenced by healthy salmon runs. Research on these interactions is essential to understanding Pacific salmon ecosystems and possible consequences for wildlife, if salmon populations in the north Pacific were to decline as they have in the Pacific Northwest (Nehlsen et al. 1991).

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Literature Cited

Barnes, V. G. 1989. The influence of salmon availability on movements and range of brown bears on southwest Kodiak Island. International Conference on Bear Research and Management 8: 305–313.

Ben-David, M., T. A. Hanley, D. R. Klein, and **D. M. Schell.** 1997. Seasonal changes in coastal and riverine mink: the role of spawning Pacific salmon. Canadian Journal of Zoology 75: 803–811.

Bilby, R. E., B. R. Fransen, and **P. A. Bisson.** 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53: 164–173.

Cummings, K. W., and **J. C. Wuycheck.** 1971. Caloric equivalents for investigations in ecological energetics. Mitteilungen Internationale Vereiningung für Theoretische und Angewandte Limnologie 18: 1–158.

Ehinger, C. E. 1930. Some studies of the American Dipper or Water Ouzel. Condor 47: 487–498.

Higgs, D. A., J. S. MacDonald, C. D. Levings, and **B. S. Dosanjh.** 1995. Nutrition and feeding habits in relation to life history stage. Pages 161–315 *in* Physiological ecology of Pacific salmon. *Edited by* C. Groot, L. Margolis, and W. C. Clarke. University of British Columbia Press, Vancouver.

Kingery, H. E. 1996. American dipper (*Cinclus mexicanus*). *In* The Birds of North America, Number 229: 1–28. *Edited by* A. Poole and F. Gill. Academy of Natural Sciences, Philadelphia, Pennsylvania and American Ornithologists' Union, Washington, D.C.

Munro, J. A. 1924. Notes on the relation of the dipper (*Cinclus mexicana unicolor*) to fishing interests in British Columbia and Alberta. Canadian Field-Naturalist 38: 48–50.

Nehlsen, W., J. E. Williams, and **J. A. Lichatowich.** 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16: 4–21.

Ormerod, S. J., M. A. Boilstone, and **S. J. Tyler.** 1985. Factors affecting the abundance of breeding dippers (*Cinclus cinclus*) in the catchment of the River Wye, mid-Wales. Ibis 127: 332–340.

Piorkowski, R. J. 1995. Ecological effects of spawning salmon on several southcentral Alaskan streams. Ph. D. dissertation, University of Alaska – Fairbanks. 177 pages.

Price, F. E., and **C. E. Bock.** 1983. Population ecology of the dipper (*Cinclus mexicanus*) in the Front Range of Colorado. Studies in Avian Biology Number 7.

Stalmaster, M. V., and **J. L. Kaiser.** 1997. Winter ecology of bald eagles in the Nisqually River drainage, Washington. Northwest Science 71: 214–223.

Welch, C. A., J. Keay, K. C. Kendall, and **C. T. Robbins.** 1997. Constraints on frugivory in bears. Ecology 78: 1105–1119.

Willson, M. F., and **K. C. Halupka**. 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9: 489–497.

Willson, M. F., S. M. Gende, and **B. H. Marston.** 1998. Fishes and the forest: expanding perspectives on fish/wildlife interactions. Bioscience 48: 455–462.

Wipfli, M. S., J. Hudson, and **J. Caouette.** 1998. Influence of salmon carcasses on stream productivity: response of biofilm and benthic macroinvertebrates in southeastern Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences 55: 1503–1511.

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Additional Extralimital Records of the Harp Seal, *Phoca groenlandica*, from the Bay of Fundy, New Brunswick

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McAlpine, Donald F., and Robert J. Walker. 1999. Additional extralimital records of the Harp Seal, *Phoca groenlandica*, from the Bay of Fundy, New Brunswick. Canadian Field-Naturalist 113 (2): 290–292.

Three recent extralimital records of the Harp Seal, *Phoca groenlandica*, from the Bay of Fundy, New Brunswick, are documented. These observations coincide with a dramatic increase in extralimital occurrences for this seal along the Maine coast from 1994-1996. Winter ocean surface currents may limit the probability that Harp Seals straying outside their normal range enter the Bay of Fundy.

Key Words: Harp Seal, *Phoca groenlandica*, Bay of Fundy, New Brunswick, distribution.

McAlpine and Walker (1990) reviewed extralimital records for the Harp Seal, *Phoca groenlandicas*, in the western North Atlantic, noting that there was only a single, verifiable, report from the Bay of Fundy during the previous 148 years. Here we document three recent additional records of Harp Seals from the northern end of the Bay of Fundy. We show that these observations coincide with a dramatic increase in extralimital occurrences for both the Harp and Hooded seals that have been documented along the Maine coast since 1994 (Stevick and Fernald 1998; McAlpine et al. *in press*). However, we also suggest that winter ocean surface currents in the Bay of Fundy limit the probability that Harp Seals straying outside their normal range will enter the Bay. McAlpine et al.(*in press*) review possible hypotheses that may explain an apparent increase in numbers of ice-breeding seals in the northern Gulf of Maine region since about 1994.

On 14 March 1995, Walker and three others, while observing seabirds, sighted an adult Harp Seal on an ice cake about 1 km offshore of Waterside, Albert County, New Brunswick (45°38′ N, 64°50′ W). The characteristic pattern produced by the dark head and "harp" were visible on the animal during the hour and more it was observed from shore through two 40× Questar scopes. Observational details and sketches have been archived in the New Brunswick Museum marine mammal observational files. On 11 April 1997 a young seal was discovered and photographed (Figure 1) by local residents on Alma Beach, Fundy National Park, Albert County, New Brunswick (45°36′ N; 64°57′ W). This photo shows a one-year-old Harp Seal. Similarly, on 18 March 1995 a small, "light gray, seal with dark spots", probably also a young Harp Seal, was observed to crawl off an ice cake which stranded at high tide on Alma Beach. These March and April

FIGURE 1. Juvenile Harp Seal, *Phoca groenlandica*, 11 April 1997, Alma Beach, New Brunswick. Photograph by P. and G. Ackerley.

observation dates are too early for young-of-the-year Harbour Seals, which are common in the region and similar in colouration to juvenile Harp Seals.

There are only 16 extralimital records for the Harp Seal in the northwest Atlantic over the 148 years previous to 1990. However, probably half of these are suspect or problematical and many are unverifiable (McAlpine and Walker 1990). Sergeant (1991) notes that Harp Seals do not now regularly reach Maine, although archaeological evidence indicates that perhaps as recently as 1000 B.P. this species was present along the New England coast (Ritchie 1969; Sanger 1987; Spiess and Hedden 1983). However, Stevick and Fernald (1998) have documented a dramatic increase in the frequency of extralimital records of Harp Seals along the Maine coast since 1994. Between 1994 and 1996 they reported there were 26 Harp Seals identified between the western shore of Penobscot Bay and Calais, Maine. Stevick and Fernald (1998) also reported 25 of the 26 sightings of Harp Seals as juveniles, with seals arriving in Maine mainly during a ten-week period starting in late January and most departing abruptly in early April. Thus, Harp Seals began appearing in Maine at a time consistent with the normal southward movement of juveniles from whelping areas on ice in the Labrador Sea off Newfoundland and in the Gulf of the St. Lawrence. Departure coincided with the onset of the molting period and the northerly spring migration.

Harp Seal records for the Bay of Fundy seem to follow a pattern that is different than that reported by Stevick and Fernald (1998). There are few observations and they all occur later in the season, during March and April. The relatively few observations from the Bay of Fundy, when compared to the Gulf of Maine, may be related to seasonal patterns of ocean surface currents in the Bay. The constant inflow from the north Atlantic that occurs along the southern entrance to the Bay of Fundy reaches a minimum during the winter months and internal eddies retain what has previously drifted in (Bumpus and Lauzier 1965 cited and illustrated in Trites and Garrett 1983). This "closed" winter circulation pattern for surface sea water may limit the probability that Harp Seals enter the Bay of Fundy during the winter when extralimital animals arrive in the region. However, the normal March-April northward movement of Harp Seals, combined with the still reduced winter ocean circulation and the near land-locked topography of the Bay of Fundy, may result in small numbers of Harp Seals finding their way into the Bay and being detained there for a period.

Acknowledgments

We thank Paula and Gerry Akerley for supplying Figure 1, as well as for details accompanying the observation. D. E. Sergeant kindly confirmed the identity of Figure 1 as a juvenile harp seal. We also thank local residents E. Bowron and N. Bowron for reporting details of their 18 March sighting to us. S. Flemming, of Parks Canada, and D. S. Christie and S. Tingley, freelance naturalists, contributed details to the 14 March 1995 observations. Peter Stevick and Thomas Fernald graciously provided us with a copy of their paper prior to its publication.

Literature Cited

Bumpus, D. F., and **L. Lauzier.** 1965. Circulation on the continental shelf off eastern North America between Newfoundland and Florida. Serial Atlas of the Maine Environment-Folio 7, American Geographical Society.

McAlpine, D. F., P. T. Stevick and **L. D. Murison.** *In press*. Increase in extralimital occurrences of ice-breeding seals in the northern Gulf of Maine region: More seals or fewer fish? Marine Mammal Science 15.

McAlpine, D. F., P. T. Stevick, L. D. Murison, and **S. D. Turnbull.** *In press*. Extralimital records of Hooded Seals (*Cystophora cristata*) from the Gulf of Maine-Bay of Fundy. Northeastern Naturalist 6.

McAlpine, D. F., and **R. H. Walker.** 1990. Extralimital records of the Harp Seal, *Phoca groenlandica*, from the western North Atlantic: A review. Marine Mammal Science 6: 248–252.

Ritchie, W. A. 1969. The archaeology of Martha's Vineyard. The Natural History Press, Garden City, New York.

Sanger, D. 1987. The Carson site and the Late Ceramic Period in Passamaquoddy, New Brunswick. Canadian Museum of Covilization, Mercury series, Archaeological Survey of Canada Paper 135. 157 pages.

Sergeant, D. E. 1991. Harp Seals, Man and Ice. Canadian Special Publication of Fisheries and Aquatic Sciences 114. Department of Fisheries and Oceans, Ottawa. 153 pages.

Spiess, A. E. and **M. H. Hedden.** 1983. Kidder Point and Sears Island in prehistory. Occasional Publications in Maine Archaelogy 3. The Maine Historic Preservation Commission, Augusta, Maine. 210 pages.

Stevik, P. T. and **T. W. Fernald.** 1998. Increase in extralimital records of Harp Seals in Maine. Northeastern Naturalist 5: 75–82.

Trites, R. W. and **C. J. R. Garrett.** 1983. Physical oceanography of the Quoddy region. Pages 9–34 *in* Marine and coastal systems of the Quoddy region, New Brunswick. *Edited by* M. L. H. Thomas. Canadian Special Publication in Fisheries and Aquatic Sciences 64.

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Record Distance for a Non-homing Movement by a Deer Mouse, *Peromyscus maniculatus*

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Bowman, Jeffrey C., Mark Edwards, Lisa S. Sheppard, and Graham J. Forbes. 1999. Record distance for a non-homing movement by a Deer Mouse, *Peromyscus maniculatus*. The Canadian Field-Naturalist 113(2): 292–293.

We report a record distance of 1768 m for a non-homing movement by a Deer Mouse, *Peromyscus maniculatus* from northwestern New Brunswick.

Key Words: Deer Mouse, *Peromyscus maniculatus*, dispersal, distance, movement, vagility, New Brunswick.

During a study of the spatial structure of small mammal populations in northwestern New Brunswick (47°22′ N, 67°25′ W) we observed a long distance movement by a Deer Mouse, *Peromyscus maniculatus*. The project design required large, nested trapping grids (grains of 125 m, 250 m, and 1000 m) and consequently we were capable of assessing long range, non-homing movements. On 9 September 1997 we captured a subadult, male Deer Mouse (weight = 15 g). The mouse was marked with a 1-g monel ear tag (National Band and Tag Co., Newport, Kansas, USA) and released at the same site. The site was a second-growth tolerant hardwood stand. Sixteen days later, on 24 September 1997, we recaptured the mouse at a trap that was a straightline distance of 1768 m away. The mouse weighed 18 g and was in good condition at recapture. The recapture site was dominated by mature softwoods (*Picea* spp. and *Abies balsamea*).

Approximately half of the 516 small mammals that were captured and marked during 1997 were recaptured multiple times at the same site. Animals not recaptured had either moved, become trap shy, or been depredated. Only 24 individuals were detected moving distances > 125 m. We have no evidence that the acts of handling and marking small mammals are themselves sufficient to stimulate a long-distance movement.

To our knowledge this is the longest reported distance for a non-homing movement by a Deer Mouse. Howard (1960) reports a movement of 1000 m , and Wegner and Merriam (1990) report movement by the closely-related *Peromyscus leucopus* of >1000 m.

Long-distance homing movements by Deer Mice have been reported (Murie 1963; Furrer 1973). Teferi and Millar (1993) report the longest of these at 1980 m.

We suspect, based on time of year, age class, and weight of the mouse, that this movement represents a dispersal. High densities of Deer Mice (10-fold increase from the same month a year previous; J. C. Bowman and G. Forbes, unpublished data) may have been the incentive for such a long-distance displacement. This observation supports recent suggestions (e.g., Kozakiewicz and Szacki 1995) that small mammals are more vagile than previously believed.

Acknowledgments

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Literature Cited

Furrer, R. K. 1973. Homing of *Peromyscus maniculatus* in the Channelled Scablands of east-central Washington. Journal of Mammalogy 54: 466–483.

Howard, W. E. 1960. Innate and environmental dispersal of individual vertebrates. American Midland Naturalist 63: 152–161.

Kozakiewicz, M., and **J. Szacki.** 1995. Movement of small mammals in a landscape: patch restriction or nomadism? Pages 78–94 *in* Landscape Approaches in Mammalian Ecology and Conservation. *Edited by* W. Z. Lidicker, Jr. University of Minnesota Press, Minneapolis, USA.

Murie, M. 1963. Homing and orientation of deer mice. Journal of Mammalogy 44: 338–349.

Teferi, T., and **J. S. Millar.** 1993. Long distance homing by the deer mouse, *Peromyscus maniculatus*. Canadian Field-Naturalist 107: 109–111.

Wegner, J., and **G. Merriam.** 1990. Use of spatial elements in a farmland mosaic by a woodland rodent. Biological Conservation 54: 263–276.

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First Confirmed Reports of Beaked Whales, *cf. Mesoplodon bidens* and *M. densirostris* (Ziphiidae), from New Brunswick

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McAlpine, Donald F., and Mike Rae. 1999. First confirmed reports of beaked whales, *cf. Mesoplodon bidens* and *M. densirostris* (Ziphiidae), from New Brunswick. Canadian Field-Naturalist 113(2): 293–295.

The first two records for New Brunswick of the little-known beaked whale genus *Mesoplodon* are documented. Based on photographs taken in 1934 and 1993 the stranded animals appear to be *M. bidens* and *M. densirostris*.

Key Words: Blainville's Beaked Whale, *Mesoplodon densirostris*, Sowerby's Beaked Whale, *Mesoplodon bidens*, New Brunswick, Canada.

As a group, the ziphiids, or beaked whales, are the least known among the cetaceans. Several species are known primarily, or exclusively, from stranded specimens and there have been few occurrences documented in Atlantic Canada (Mead 1989). There are two Canadian records for Blainville's Beaked Whale, *Mesoplodon densirostris*, and a single report for True's Beaked Whale, *Mesoplodon mirus*, all in Nova Scotia (Allen 1939; McKenzie 1940; Sergeant, Mansfield and Beck 1970). Single and multiple strandings and sightings of Sowerby's Beaked Whale, *Mesoplodon bidens*, in Canada, involving 19 animals, have all been recorded on and near Newfoundland and Labrador (Lein and Barry 1990). Gaskin (1997) made "two fleeting observations in rather poor weather of a small beaked whale in the lower Bay of Fundy" in 1985, which he suggested may have been *Mesoplodon bidens*. Although several authors (Squires 1968; Beatty 1989) have suggested that *Mesoplodon* sp., may occur in New Brunswick waters, there have been no confirmed records published in the scientific literature to date. Gaskin (1983) noted that there was a stranding record for *Mesoplodon bidens* in the Bay of Fundy, but corrected this error in Gaskin (1985), noting that the species had stranded "near our region". Presumably he refers to the Newfoundland and Labrador records cited above. Here I document two occurrences of beaked whales from New Brunswick. Unfortunately, these records are based on photographic evidence only and species identifications are therefore tentative.

On 24 February 1934, a 4.6 m *Mesoplodon* sp. stranded dead on the shore at Duck Cove, Saint John County, New Brunswick (45°14′ N 66°05′ W). The

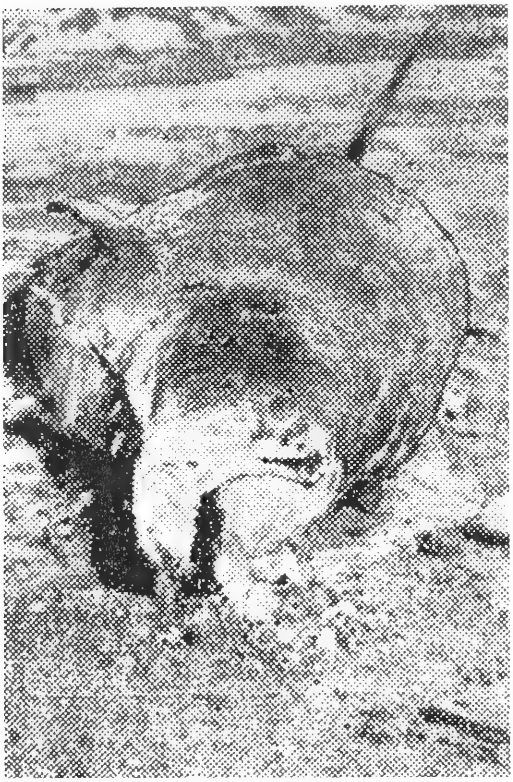

FIGURE 1. Probable *Mesoplodon densirostris* stranded on 28 February 1934 at Duck Cove, Saint John, New Brunswick.

FIGURE 2. Probable *Mesoplodon bidens* stranded near St. Thomas-de-Kent, New Brunswick, 28 September 1993.

stranding was reported in the local press[1] two days later and two photographs of the animal presented (Figure 1). William McIntosh, then curator at the New Brunswick Museum, examined the animal and expressed the opinion that it was a species of beaked whale, which it clearly is. The strongly curved jawline suggests *Mesoplodon densirostris*. *Mesoplodon densirostris* is extremely rare in Canadian waters and the Canadian distribution is considered on the periphery of the species range (Houston 1990). The newspaper account refers to the animal being "stripped of … ivory tusk protuberances". This information, combined with dorsal and ventral surfaces that both appear to be darkly coloured, indicate the animal is likely a male (Mead 1989). A later note in the newspaper[2] reported that the head of the animal had been removed for examination and addition to the New Brunswick Museum collection and that "uncertainty still connected with the identity of the monster … will be cleared up". Unfortunately, there is no definite record that the specimen was ever received or examined at the museum, or added to the collection.

On 28 September 1993, a 4.8 m *Mesoplodon* sp. was discovered dead on the shore about 2 km south of St. Thomas-de-Kent, Kent County, New Brunswick (46°27′ N 64°38′ W). The stranding was reported in a local paper[3] on 3 October, by which time the animal had been removed from the beach and buried. Attempts to have the animal exhumed have been unsuccessful, but the burial site nearby in Cap Pelé, Westmorland County has been visited and co-ordinates recorded using a GPS (46°10.616′ N 64°14.158′ W). Photographs (Figure 2), provided by the journalist who viewed the whale, plus others obtained by canvassing local residents, have been archived in the New

[1]Old salt examines Duck Cove oddity says its a grampus. 16 February 1934, *The Evening Times-Globe*, Saint John, New Brunswick, Section 2, Page 1.

[2]Dr. Wm. McIntosh starts post-mortem on beach monster. 3 March 1934, *The Evening Times-Globe*, Saint John, New Brunswick, Section 2, Page 1.

[3]Triste fin pour un immense dauphin on en fera de la mouleé pour les vaches. 13 Octobre 1993, *Pro-Kent*, Richibucto, New Brunswick, Page 18.

Brunswick Museum marine mammal files. Colour photographs show a steel-gray animal, somewhat lighter ventrally than dorsally, with a prominent dark oval patch around the eye. There is a noticeable bulge in front of the blow-hole, a fairly long beak, a prominently concave, unnotched tail fluke, an obvious, strongly falcate dorsal fin, and very limited scarring. Comparison with published photographs and descriptions (Mead 1989; Watson 1981) suggest this animal is *Mesoplodon bidens*. Teeth are not visible, indicating this animal is a female. Lien et al. (1990) state that *Mesoplodon bidens* frequent western North Atlantic coasts fairly regularly. Mead (1989) notes that this is a species of cold temperate waters of the North Atlantic and Watson (1981) reports that *Mesoplodon bidens* is the most commonly stranded beaked whale.

The records documented here appear to represent only the third Canadian report for *Mesoplodon densirostris* and the first Canadian occurrence of *Mesoplodon bidens* outside the Newfoundland-Labrador region. These reports indicate that *Mesoplodon* sp. may be expected in New Brunswick waters on very rare occasions.

Acknowledgments

We are grateful to St. Thomas-de-Kent residents, who assisted with the initial contact with personnel at W. E. Acres Crabmeal Ltd, the site of the whale burial. M. Allain, E. Melanson, and B. Boulianne all generously allowed copies of photographs to be archived in the New Brunswick Museum files. R. Baird, J. Lien, J. Mead and L. Murison kindly provided comments on photographs, however the final determinations are those of D. F. McAlpine.

Literature Cited

Allen, G. M. 1939. True's beaked whale in Nova Scotia. Journal of Mammalogy 20: 259–260.

Beatty, T. 1989. Whales of the Bay of Fundy. Sunbury Shores Arts and Nature Centre, St. Andrews. New Brunswick.

Gaskin, D. E. 1983. The marine mammal community. Pages 245–268 *in* Marine and coastal systems of the Quoddy region, New Brunswick. *Edited by* M. L. H. Thomas. Canadian Special Publication of Fisheries and Aquatic Sciences 64.

Gaskin, D. E. 1997. Marine mammals of the Bay of Fundy. Bulletin Number 1, Grand Manan Whale and Seabird Research Station. North Head, New Brunswick.

Houston, J. 1990. Status of Blainville's Beaked Whale, *Mesoplodon densirostris*, in Canada. Canadian Field-Naturalist 104: 117–120.

Lien, J., and **F. Barry.** 1990. Status of Sowerby's Beaked whale, *Mesoplodon bidens*, in Canada. Canadian Field-Naturalist 104: 125–130.

Lien, J., F. Barry, K. Breeck, and **U. Zuschlag.** 1990. Multiple strandings of Sowerby's Beaked Whales, *Mesoplodon bidens*, in Newfoundland. Canadian Field-Naturalist 104: 414–420.

McKenzie, R. A. 1940. Some marine records from Nova Scotian fishing waters. Proceedings of the Nova Scotia Institute of Science 20: 42–46.

Mead, J. G. 1989. Beaked Whales of the genus *Mesoplodon*. Pages 349–430 *in* Handbook of Marine Mammals, Volume 4. *Edited by* S. H. Ridgway and R. Harrison. Academic Press, London.

Sergeant, D. E., A. W. Mansfield, and **B. Beck.** 1970. Inshore records of Cetacea for eastern Canada. Journal of the Fisheries Research Board of Canada 27: 1903–1915.

Squires, W. A. 1968. The mammals of New Brunswick. Monographic Series Number 5, New Brunswick Museum, Saint John, New Brunswick.

Watson, L. 1981. Sea guide to whales of the world. Nelson Canada, Scarborough, Ontario.

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Threatened Species Monitoring: Results of a 17-year Survey of Pitcher's Thistle, *Cirsium pitcheri*, in Pukaskwa National Park, Ontario

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As part of the ongoing ecological monitoring initiatives at Pukaskwa National Park, Ontario, park staff have been monitoring Pitcher's Thistle (*Cirsium pitcheri*, Asteraceae) annually since 1981. This species is endemic to the Great Lakes region and is considered "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Over 17 years, the population has fluctuated greatly (mean = 401.7 plants with a standard deviation of 182.9). This fluctuation is attributed to the bursting of an upstream beaver dam in 1986 that wiped out much of the colony along the stream banks. The population remained low (< 300 total plants) for five years before rebounding in 1991, reaching a peak of 497 plants, in 1996. Although natural succession is of concern, there is no reason to believe that the population will not survive under current management practices.

Key Words: Pitcher's Thistle, *Cirsium pitcheri*, endemic, threatened species, monitoring, Pukaskwa National Park, Great Lakes, Ontario.

Pitcher's Thistle (*Cirsium pitcheri* (Torr. ex Eat.) Torr. and A. Gray) is an endemic to the Great Lakes shoreline (White et al. 1983). The majority of its population is found along the eastern shore of Lake Michigan and the western shore of Lake Huron in open sandy environments (Gleason and Cronquist 1963). Mosquin (1990*) suggests that the plant is an early successor into sandy environments, and that periodic disturbance is vital to its survival. However, the plant is susceptible to habitat destruction from White-tailed Deer (*Odocoileus virginianus*) browsing (Phillips and Maun 1996) and human development and trampling (D'Ulisse and Maun 1996).

The *C. pitcheri* is considered rare in Ontario (Argus and White 1977), and in 1988, was classified as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) based on a status report by Keddy (1987*). The Pukaskwa plants represent a peripheral population, since there are no other records on the north shore of Lake Superior.

Site Location

Pukaskwa National Park is located on the north shore of Lake Superior, 30 km south of Marathon, Ontario. The park measures 1878 km^2 with over 100 km of coastline from the Pic River at the northern boundary to the Pukaskwa River in the south. The cooling influence of Lake Superior provides suitable habitat for many arctic-alpine species including Franklin's Lady Slipper (*Cypripedium passerinum* Rich.) and Northern Twayblade (*Listera borealis* Morong.). Although there are numerous sandy environments along the north shore of Lake Superior, *C. pitcheri* is found only in Oiseau Bay (48°24′01″N 8611′07″W), 30 km south of the park entrance at Hattie Cove. The plants are protected from direct human interference by low fences around the colonies with notification signs informing visitors of the plants' importance.

Methods

When Pukaskwa National Park was established in 1978, efforts were made to begin a monitoring program for some of the unique flora of the park. The original study design was produced by C. Keddy (1982*) and later updated by T. Mosquin (1990*). In 1981, park staff began annual monitoring *C. pitcheri* found along Oiseau Bay in two areas approximately 200 m apart (Creek Beach and Crescent Beach).

Methods for monitoring *C. pitcheri* are outlined in the *Rare Plant Management Plan* for Pukaskwa National Park (Parks Canada 1986*). The survey is a total count, at 1.25 m intervals (Reside 1991*). Individual plants are pegged and numbered as per their life cycle, i.e., seedling (first year), rosettes (> 1 year, non-flowering), and flowering plants plus the growing environment (sandy, woody debris, etc.) in which the plant is recorded. Successional changes to the surrounding environment and other associated species are also recorded.

Mosquin (1990*) found that the methodology for counting flowering plants and rosettes had been altered slightly between 1981 and 1985. As a result, he applied a conversion factor to the 1981–1985 data, by analyzing the ratio of single to multiple stemmed plants among rosettes in 1986, 1987 and 1990 (Mosquin 1990*).

*see Documents Cited section.

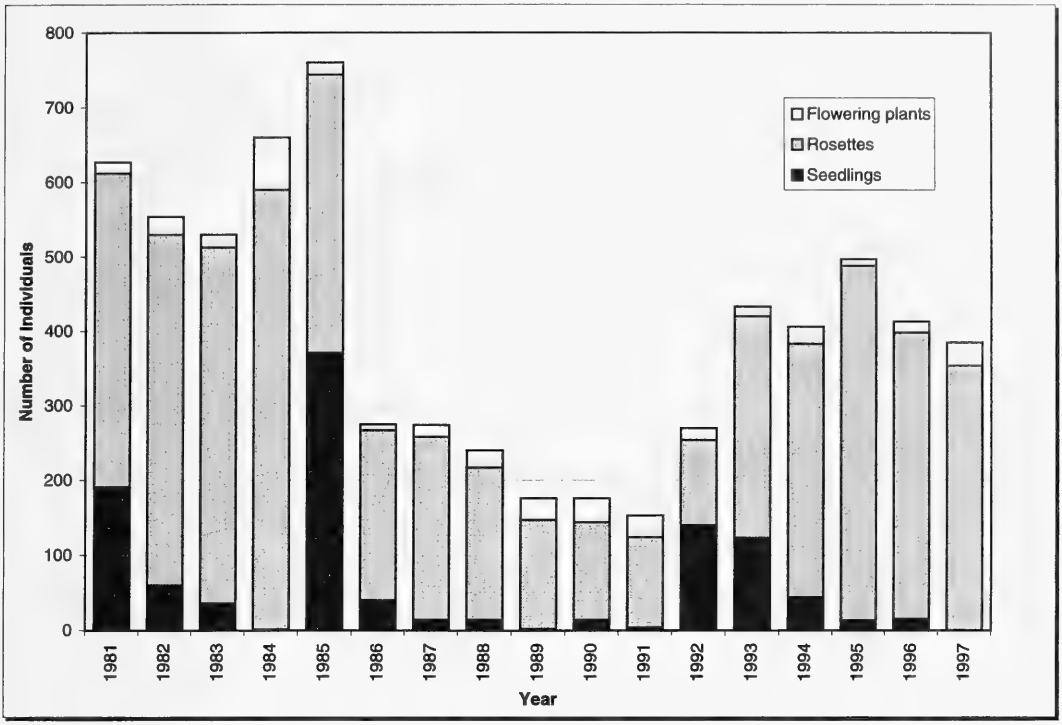

FIGURE 1. *Cirsium pitcheri* populations, 1981–1997, Pukaskwa National Park, Ontario.

Descriptive statistics such as mean and standard deviation have been applied to the results to reveal trends in the data over the 17-year period.

Results

Over 17 years the data indicates a mean total population of 401.7 plants along the two beaches within Pukaskwa National Park (Figure 1). There is a standard deviation of 182.9. There was a high of 760 individuals in 1985 and a low of 153 in 1991. In 1986, a beaver dam upstream from the thistle colony burst releasing a substantial volume of water (Sahanatien 1985*). This forced the re-routing of the creek near its mouth clearing out 63% of the thistle population. Between 1986-1991, the population remained low (< 300 total population) until 1991 with a population of 153 individuals. Since 1991 the population has rebounded to a high of 497 in 1996.

Discussion

The *C. pitcheri* population appears to have survived the catastrophic impact to its habitat in 1986. As suggested by Mosquin (1990*), periodic disturbance may actually assist the survival of the plant by reducing the encroachment of later successional species.

Since 1986, however, the re-routing of the creek into Oiseau Bay has reduced the annual level of disturbance at the site (Mosquin 1990*). The population near Creek Beach (the larger of the two concentrations), is no longer influenced by deposition or periodic water fluctuations. With this lack of disturbance, Mosquin suggested that the population would have difficulty competing with other encroaching vegetation (Mosquin 1990*). However, the total plant population has actually increased since 1991, initiated by a higher number of seedlings in 1992. Reside (1992*) suggests that the cool weather and moist conditions that were prevalent during the summer months of 1992 may have contributed to the higher germination rate. Thus, the favourable growing conditions of 1992 may have propagated enough seedlings to give the population a reprieve from successional vegetation. It is too early to detect whether succession will eventually limit the *C. pitcheri* population.

The *C. pitcheri* population at Pukaskwa National Park remains unthreatened by habitat destruction from human development and trampling and deer browsing, as found in the Pinery Provincial Park on Lake Huron (Phillips and Maun 1996; D'Ulisse and Maun 1996). Therefore, this population is a very critical one to the protection of the plant in Canada. *C. pitcheri* is within a Special Preservation Zone within Pukaskwa National Park, free from development or human activity. Also, White-tailed Deer have not been identified consistently within Pukaskwa National Park.

Based on data collected since 1981, the population of *C. pitcheri* at Oiseau Bay, in Pukaskwa National Park appears to remain viable with an average of over 400 individual plants. The current population has rebounded significantly from a 1991 population of 153 individual plants. Continued natural disturbance will be vital to the survival of this species. However, due to succession and genetic isolation, it remains difficult to predict the long term status of this species in Pukaskwa.

Acknowledgments

The results of this type of study would not have been possible without the continuing support of Pukaskwa National Park and the Warden Service, particularly Larry Vien, Bob Reside, Vicki Sahanatien, Adam Moreland, Louis Nabigon, and the numerous staff and volunteers. Erich Haber commented on the original draft, and subsequent drafts.

Documents Cited (marked * in text)

Keddy, C. 1982. An ecological study of *Cirsium pitcheri* (Pitcher's Thistle) in Pukaskwa National Park. Consultant Report to Parks Canada. 87 pages.

Keddy, C. 1987. Status report on Pitcher's thistle, *Cirsium pitcheri*, a threatened species in Canada. COSEWIC Report, Canadian Wildlife Service, Ottawa, Ontario.

Mosquin, T. 1990. A review of monitoring procedures and management guidelines for the Beach Thistle (*Cirsium pitcheri*) in Pukaskwa National Park, Final Report. prepared for the Canadian Parks Service, Pukaskwa National Park. 31 pages.

Parks Canada. 1986. Pukaskwa National Park rare plant management plan. Environment Canada - Parks. Heron Bay, Ontario. 167 pages.

Reside, B. 1991. *Cirsium pitcheri* monitoring report Pukaskwa National Park 1991. Unpublished internal report, Warden Service, Pukaskwa National Park, Ontario.

Reside, B. 1992. *Cirsium pitcheri* monitoring report Pukaskwa National Park 1992. Unpublished internal report, Warden Service, Pukaskwa National Park, Ontario.

Sahanatien, V. 1985. Impact assessment of storm damage to the Pitcher's Thistle colonies of Pukaskwa National Park. Parks Canada Report. 17 pages.

Literature Cited

Argus, G. W., and **D. J. White.** 1977. The rare vascular plants of Ontario. National Museum of Natural Sciences, Syllogeus 14. 63 pages.

D'Ulisse, A., and **M. A. Maun.** 1996. Population ecology of *Cirsium pitcheri* on Lake Huron sand dunes: II. Survivorship of plants. Canadian Journal of Botany 74: 1701–1707.

Gleason, H. A., and **A. Cronquist.** 1963. Manual of vascular plants of northeastern United States and adjacent Canada. Van Nostrand Reinhold Company, New York. 810 pages.

Phillips, T., and **M. A. Maun.** 1996. Population ecology of *Cirsium pitcheri* on Lake Huron sand dunes I. Impact of white-tailed deer. Canadian Journal of Botany 74: 1439–1444.

White, D. J., R. V. Maher, and **C. J. Keddy.** 1983. *Cirsium pitcheri* (Torr. ex Eat.) T.&G. *in* Atlas of the rare vascular plants of Ontario, Part 2. *Edited by* G. W. Argus, K. M. Pryer, D. J. White, and C. J. Keddy 1987. Botany Division, National Museum of Natural Sciences, Ottawa, Canada.

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Status of the Golden Paintbrush, *Castilleja levisecta* (Scrophulariaceae) in Canada[1]

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Douglas, George W., and Michael Ryan. 1999. Status of the Golden Paintbrush, *Castilleja levisecta* (Scrophulariaceae) in Canada. Canadian Field-Naturalist 113(2): 299–301.

In Canada, Golden Paintbrush, *Castilleja levisecta*, has been collected on southeastern Vancouver Island and some adjacent small islands. Populations at two sites have been confirmed in recent years while the species has probably been extirpated at seven previous collection sites. The confirmed populations collectively represent the northern range limit of *C. levisecta*. Threats to the two confirmed populations include marine oil disasters and increasing presence of introduced species.

Key Words: Golden Paintbrush, *Castilleja levisecta*, British Columbia, endangered, distribution, population size.

The Golden Paintbrush, *Castilleja levisecta* Greenman, is a member of a genus of about 150 to 200 species, most of which occur in North America (Ownbey 1959). It is one of 20 species occurring in British Columbia (Douglas 1991) and about 25 occurring in Canada (Scoggan 1979). *Castilleja levisecta* is not known to have any medicinal or economic uses.

Castilleja levisecta is a multistemmed perennial herb, 10-50 cm tall, in which the non-showy, two-lipped flowers are enclosed in bright yellow bracts (Figure 1). The glandular-pubescent leaves are entire to lobed.

Distribution

Historically, *C. levisecta* ranged from southeastern Vancouver Island to central Oregon (Peck 1961). Today, it is known only from two islands off southeastern Vancouver Island, the San Juan Islands, and the Puget Trough area of Washington State (Sheenan and Sprague 1984; Douglas et al. 1998).

Habitat

The extant populations of *Castilleja levisecta* grow on shallow soils in very dry microsites exposed to ocean spray. Vegetation is mainly grass-dominated with Early Hairgrass (*Aira praecox*), Orchardgrass (*Dactylis glomerata*), Hedgehog Dogtail (*Cynosurus echinatus*) and Sweet Vernalgrass (*Anthoxanthum odoratum*) often present.

General Biology

Very little information is available on the general biology of *Castilleja levisecta*. It is likely that this species parasitizes the roots of other species occurring in the same habitat. No studies have been done to identify these species. Many aspects of the population dynamics of *C. levisecta* are not known including the average life-span, the frequency with which seeds germinate and become established, and the competitive ability of *C. levisecta* with other species.

FIGURE 1. Habit of *Castilleja levisecta*.

[1]This paper is based primarily on a COSEWIC status report submitted by the authors and approved by COSEWIC in April 1995. It has been revised to include more recent information. Official COSEWIC reports are available from the COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada.

TABLE 1. Location of *Castilleja levisecta* populations in Canada.

Collection Site	Last Observation	Collector	Population (number of plants/area)
Cedar Hill (Victoria)	1887	J. Macoun	Extirpated
South Wellington	1898	J. Fletcher	Extirpated
Foul Bay (Victoria)	1918	W. C. Carter	Extirpated
Sidney	1927	V. Goddard	Extirpated
Lost Lake (Victoria)	1945	G. Hardy	Extirpated
Dallas Road Cliffs (Victoria)	1969	L. J. Clark	Extirpated
Beacon Hill (Victoria)	1991	T. C. Brayshaw	Extripated
Trial Island (Victoria)	1992	G. W. Douglas	2560/4900 m^2
Alpha Islet (Victoria)	1994	S. Cannings	1000/100 m^2

Population Size and Trends

Castilleja levisecta has been observed at nine sites in Canada on southern Vancouver Island or adjacent islands (Table 1, Figure 2). Populations at seven of these sites are now considered extirpated. The population at Beacon Hill consisted of three plants in 1991. Although the site has been visited every year since then, not a single plant has been located thus the plant is probably extirpated at this site. The populations on Alpha Islet (1000 plants over 100 m^2 in 1994) and Trial Island (2560 plants over 4900 m^2 recorded in 1992) remained stable during 1992 to 1996.

Limiting Factors

In the past, the most direct threat to populations of *C. levisecta* was that of habitat destruction. Grass-dominated meadows occur on gentle slopes near the most climatically-favourable coastal areas of British Columbia and have been subjected to extensive agricultural and residential development. Although the two known Canadian populations occur in protected Ecological Reserves, recreational use of the islands could affect the species. Competition from aggressive introduced species is probably the most direct threat. There is also the possibility of a marine oil disaster affecting the islands, since they are located on one of the most busy oil traffic lanes in the world.

Special Significance of the Species

Castilleja levisecta belongs to a relatively small group of species with a restricted Pacific Coast range that have their northern limits in southern British Columbia. The importance of these peripheral populations, especially with respect to their genetic characteristics, has yet to be studied adequately. This species may prove to be a worthwhile subject for genetic research.

Protection

The British Columbia Conservation Data Centre has ranked this species as S1 and placed it on the Ministry of Environment, Lands and Parks Red list. This is the most critical category for imperiled rare native vascular plants in the province. The S1 rank is that of The Nature Conservancy of the United States

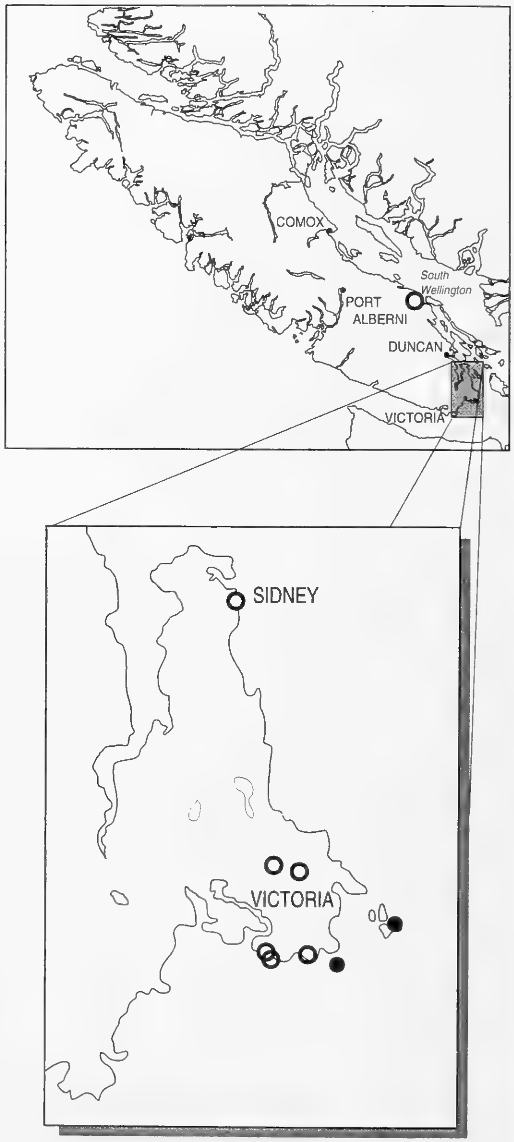

FIGURE 2. Distribution of *Castilleja levisecta* in British Columbia. (○ - extirpated sites, ● - recently confirmed sites).

where S1 is considered "critically imperiled because of extreme rarity (5 or fewer extant occurrences or very few remaining individuals) or because of some factor(s) making it especially vulnerable to extirpation or extinction".

In the remainder of its range, this taxon has been ranked S1 by the Washington Natural Heritage Program, where there are seven extant sites (Sheenan and Sprague 1984) and SX (extirpated) by the Oregon Natural Heritage Program. It has been globally ranked by The Nature Conservancy of the United States as G1. The latter rank carries the same definition as the S1 Rank above.

There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The two British Columbia populations of *Castilleja levisecta* are protected to a certain extent by their location on public property in ecological reserves.

Evaluation of Status

Castilleja levisecta is considered by the British Columbia Conservation Data Centre to be endangered in Canada and is known only from two extant populations restricted to two islands adjacent to southeastern Vancouver Island. The prognosis for this species is not good considering the threats posed by aggressive exotic species and potential marine oil disasters.

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Literature Cited

Douglas, G. W. 1991. Scrophulariaceae. Pages 80–101 *in* The vascular plants of British Columbia. Part 3 - Dicotyledons (Primulaceae through Zygophyllaceae). *Edited by* G. W. Douglas, G. B. Straley, and D. Meidinger. Special Report Series 3 British Columbia Ministry of Forests, Victoria. 177 pages.

Douglas, G. W., G. B. Straley, and **D. Meidinger.** 1998. Rare vascular plants of British Columbia. British Columbia Ministry of Environment, Lands and Parks, Victoria. 520 pages.

Ownbey, M. 1959. *Castilleja*. Pages 295–326 *in* The vascular plants of the Pacific Northwest Part 4: Ericaceae to Campanulaceae. *Edited by* C. L. Hitchcock, A. Cronquist, and M. Ownbey. University of Washington Press, Seattle. 510 pages.

Peck, M. E. 1961. A manual of the higher plants of Oregon. 2nd edition. Binsfort and Mort, Portland. 866 pages.

Scoggan, H. J. 1979. The flora of Canada. Part 4 - Dicotyledoneae (Loasaceae to Compositae). National Museum of Natural Sciences Publication in Botany Number 7.

Sheenan, M., and **N. Sprague.** 1984. Report on the status of *Castilleja levisecta* Greenman. Washington Natural Heritage Program, Olympia, Washington. 24 pages.

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Construction of a Natal Den by an Introduced River Otter, *Lutra canadensis*, in Indiana

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Johnson, Scott A., and Kim A. Berkley. 1999. Construction of a natal den by an introduced River Otter, *Lutra canadensis*, in Indiana. Canadian Field-Naturalist 113(2): 301–304.

We describe construction of a nest-like structure at a natal den site in a shallow marsh in southern Indiana by an adult female River Otter (*Lutra canadensis*). Construction appeared to coincide with periods of high water, perhaps to avoid mortality of dependent pups from repeated flood events.

Key Words: River Otter, *Lutra canadensis*, natal den, Indiana.

North American River Otters (*Lutra canadensis*) select den or resting sites based on availability of suitable shelters that offer protection and seclusion (Melquist and Hornocker 1983). Otters are not known to excavate or construct dens, and often use existing burrows dug by other species such as Muskrat (*Ondatra zibethicus*), Woodchuck (*Marmota monax*), Nutria (*Myocaster coypus*), and Beaver (*Castor canadensis*) (McDonald 1989; Melquist and Dronkert 1987; Toweill and Tabor 1982). Natural and artificial shelters such as log jams, undermined root cavities, tree falls, riparian vegetation, hollow logs, and duck blinds also are used (Griess 1987; McDonald 1989;

Melquist and Dronkert 1987; Toweill and Tabor 1982).

River Otter natal den sites have not been throughly described. Liers (1951) reported on two litters in Wisconsin raised in Woodchuck burrows. In Idaho, Melquist and Hornocker (1983) reported young raised in an abandoned fox (*Vulpes vulpes*) den and an exposed brush pile. Natal dens in Alaska were located in burrows beneath rotted stumps and a natural rock cavity (Woolington 1984). We describe the construction of a nest-like structure at a natal den site by a female otter translocated from Louisiana to Indiana.

Methods and Materials

We released 25 River Otters (15M:10F) obtained from Louisiana on 17 January 1995 at the 3125-ha Muscatatuck National Wildlife Refuge (MNWR) in Jackson and Jennings counties in southern Indiana. The MNWR lies 5 km east of Seymour in the Scottsburg Lowland Section of the Bluegrass Natural Region (Homoya et al. 1985). Excluding Seymour, the area is sparsely populated and rowcrop production (i.e., corn and soybeans) comprises the major land use. The refuge maintains about 525 ha of permanent or seasonal water in ten moist-soil units ($\bar{x}$ = 13.5 ± 7.0 ha), three bottomland forest units ($\bar{x}$ = 27.6 ± 9.2 ha), several impoundments, natural marshes, and numerous small ponds. Storm Creek and Mutton Creek flow, respectively, 5.3 km and 6.1 km through MNWR. The Vernon Fork of the Muscatatuck River forms the southern boundary (6.6 km) of the refuge. Two impoundments, Stanfield Lake (55 ha) and Richart Lake (43 ha), are the largest open-water habitats on MNWR. In contrast, 306-ha Moss Lake supports emergent and scrub-shrub vegetation and seasonally-flooded timber stands. This release was the initial attempt to restore extirpated otter populations to suitable habitats throughout Indiana (Johnson and Madej 1994). To evaluate the release, we monitored the activities of 15 otters (9M:6F) for one year using intraperitoneal transmitters.

Observations

On 13 February 1995 (27 days post-release), we observed F47, an adult radioed female of unknown age, mating with a radioed male in Moss Lake in the southwest corner of the refuge. She remained on MNWR for > 1 year after the release where she restricted most of her activity to Moss Lake (110 of 121 relocations). In early March 1996, her movements became confined to a shallow marsh dominated by Buttonbush (*Cephalanthus occidentalis*) and Broad-Leaved Cattail (*Typha latifolia*) on Sandy Branch, a slow-flowing tributary into western Moss Lake. On 13 March, we located her beneath a hummock island (ca. 4.5 m long, 3.6 m wide) formed by root structures of several American Sycamore (*Platanus occidentalis*) trees. No sign or evidence of otter activity was present, and we assumed she would use the tree root cavity system beneath the hummock as a natal den site. On 3 April, we located F47 in the den, but found a loose mound of cattail stalks and dried grasses on top of the hummock (Figure 1A). The mound was about 1 m long, 45 cm high, and had what appeared to be a 15-cm diameter entrance hole. On 11 April, the female was again located beneath the hummock, but the mound lacked new material and the entrance hole appeared disheveled and unused. On 1 May, we flushed the female from the top of the mound, which was now noticeably larger and more structured and complex (Figure 1B). It measured about 1 m in height and had at least two entrance chambers, one of which contained an otter pup. A shallow depression was evident on top, perhaps used by the female for basking or sentinel use. On 8 May, the Sycamore trees were uprooted at their base by high winds, and a subsequent visit revealed a complex root cavity system beneath the hummock island. The nest-like structure had remained intact, but the den appeared abandoned and F47 was < 100 m from the site.

Discussion

Surface den construction by River Otters has not been reported previously; however, our observations are confounded by the fact that they were of an animal introduced into habitats markedly different from its source location. Otters in coastal marshes of Louisiana use old muskrat houses or nutria burrows (Lowery 1974), but they are not known to construct their own den sites (R. G. Linscombe, Louisiana Department of Wildlife and Fisheries, personal communication). Our account of den construction may represent atypical behavior in response to a unique situation in unfamiliar habitats.

Although River Otters are adaptive and use a variety of den sites, selection of natal dens may be important because of the potential for spring flooding. Newborn otters depend on the female for food, protection, and shelter, and pups do not emerge from the natal den until about 8 weeks of age (Liers 1951; Melquist and Hornocker 1983). Pup survival could be jeopardized if early spring snow melt or excessive rainfall floods the den before the pups become mobile and less dependent. To minimize this risk, female otters should select natal dens that are protected, secure, and unlikely to flood. Two Woodchuck burrows used as natal dens in Wisconsin were located on hillsides about 45 m above the high-water mark and on a 150-m high bluff about 0.8 km from water (Liers 1951). Natal dens in southeast Alaska were located from 0.25 to 0.8 km from shore and at elevations up to 210 m (Woolington 1984). Melquist and Hornocker (1983) felt canid dens in Idaho would serve as natal dens

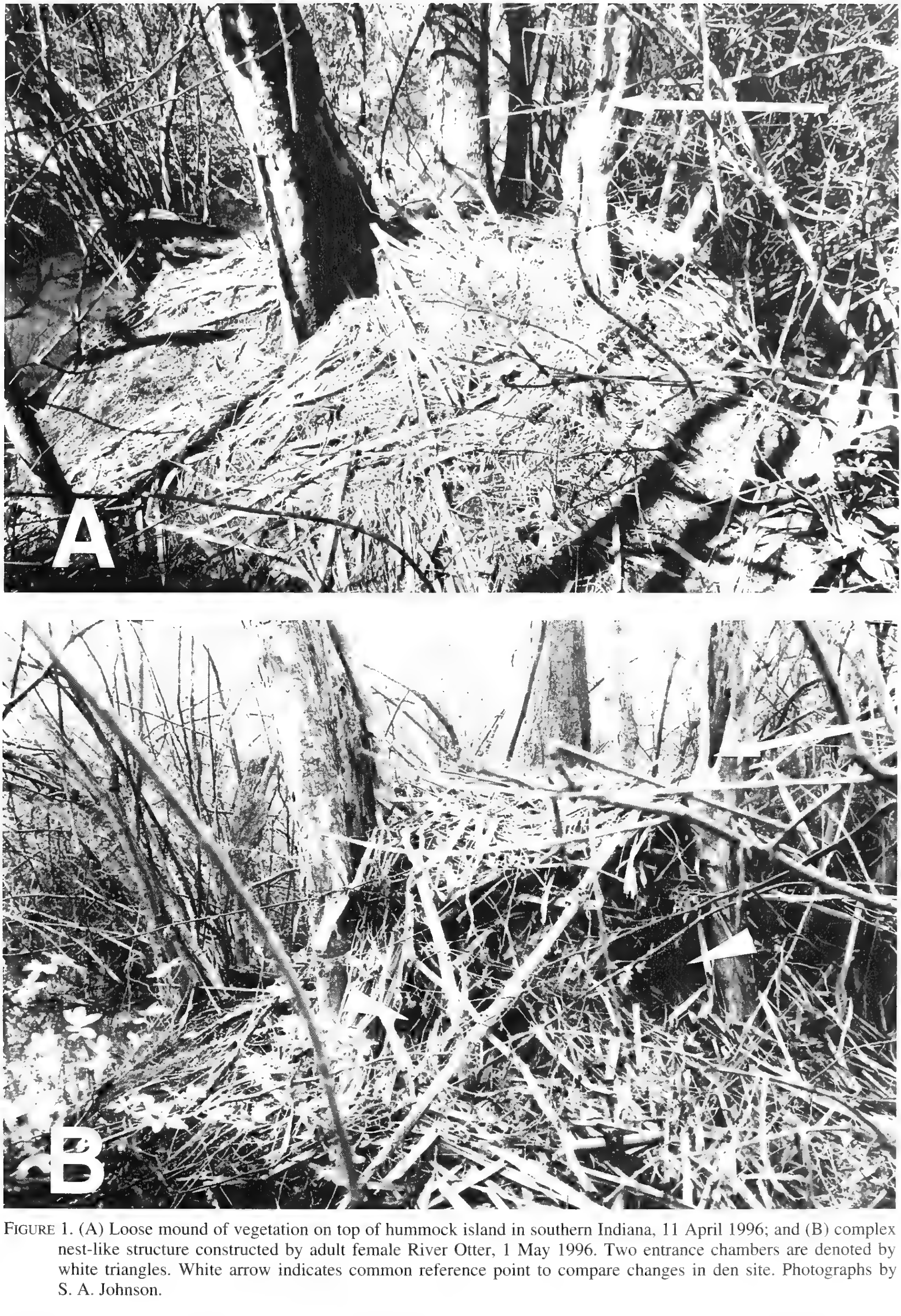

FIGURE 1. (A) Loose mound of vegetation on top of hummock island in southern Indiana, 11 April 1996; and (B) complex nest-like structure constructed by adult female River Otter, 1 May 1996. Two entrance chambers are denoted by white triangles. White arrow indicates common reference point to compare changes in den site. Photographs by S. A. Johnson.

for otters because they were often on bluffs above streams and unlikely to flood during spring run-off. Similarly, Harper (1981) found holts of the European Otter (*Lutra lutra*) were located in situations where flooding was unlikely or on small tributaries with low rates of water flow.

Yeager (1938) speculated otters would use temporary or emergency refuges if natal dens were flooded at or shortly after whelping. We suggest F47 constructed the nest-like structure in response to periodic flooding that had inundated her original den beneath the hummock island. Once the den was discovered, we limited our visits to avoid disturbance, and as a result, never observed her adding vegetation to the structure. It is unlikely that other species [e.g., Muskrat, Canada Goose (*Branta canadensis*)] built the nest because female otters aggressively protect their young (Toweill and Tabor 1982) and would not tolerate other species near their litters. Further, Liers (1951) reported an otter nest in a dry saw-grass marsh in Florida and other species of otters are known to construct beds or couches (Hewson 1969).

Based on localized movements of F47 in early March and the first known use of the den, her litter was likely born in mid-March. On 19-20 March, MNWR received >22 cm snow that caused widespread flooding for several days. Air space beneath the island was likely restricted at this time when her pups were <2 weeks old, which coincides with our first observation of the structure on 3 April. The nest appeared unused on 11 April after water levels had receded, but MNWR again reached flood stage after 10.9 and 14.2 cm rain fell on 21-24 April and 28-29 April, respectively. High water again probably inundated the cavity beneath the hummock, which may have prompted further construction and subsequent use of the larger structure that we observed on 1 May.

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Literature Cited

Griess, J. M. 1987. River otter reintroduction in Great Smoky Mountains National Park. M.S. thesis, University of Tennessee, Knoxville. 109 pages.

Harper, R. J. 1981. Sites of three otter (*Lutra lutra*) breeding holts in fresh-water habitats. Journal of Zoology (London) 195: 554–556.

Hewson, R. 1969. Couch building by otters (*Lutra lutra*). Journal of Zoology (London) 159: 524–527.

Homoya, M. A., D. B. Abrell, J. R. Aldrich, and **T. W. Post.** 1985. The natural regions of Indiana. Proceedings of the Indiana Academy of Science 94: 245–268.

Johnson, S. A., and **R. J. Madej.** 1994. Reintroduction of the river otter in Indiana: feasibility study. Final report, Indiana Department of Natural Resources, Indianapolis. 30 pages + appendices.

Liers, E. E. 1951. Notes on the river otter (*Lutra canadensis*). Journal of Mammalogy 32: 1–9.

Lowery, G. H., Jr. 1974. The mammals of Louisiana and its adjacent waters. Louisiana State University Press, Baton Rouge. 565 pages.

McDonald, K. P. 1989. Survival, home range, movements, habitat use, and feeding habits of reintroduced river otters in Ohio. M.S. thesis, Ohio State University, Columbus. 129 pages.

Melquist, W. E., and **A. E. Dronkert.** 1987. River otter. Pages 627–641 *in* Wild furbearer management and conservation in North America. *Edited by* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. Ministry of Natural Resources, Toronto, Ontario. 1150 pages.

Melquist, W. E., and **M. G. Hornocker.** 1983. Ecology of river otters in west central Idaho. Wildlife Monograph 83. 60 pages.

Toweill, D. E., and **J. E. Tabor.** 1982. River otter (*Lutra canadensis*). Pages 688–703 *in* Wild mammals of North America: biology, management, and ecology. *Edited by* J. A. Chapman and G. A. Feldhammer. Johns Hopkins University Press, Baltimore. 1147 pages.

Woolington, J. D. 1984. Habitat use and movements of river otters at Kelp Bay, Baranof Island, Alaska. M.S. thesis, University of Alaska, Fairbanks. 147 pages.

Yeager, L. E. 1938. Otters of the delta hardwood region of Mississippi. Journal of Mammalogy 19: 195–201.

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First Record of Coccidiosis in Wolves, *Canis lupus*

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Mech, L. David, and Harold J. Kurtz. 1999. First record of coccidiosis in Wolves, *Canis lupus*. Canadian Field Naturalist 113(2): 305–306.

Three 4-month-old Wolf (*Canis lupus*) pups in the Superior National Forest of Minnesota died during August and September 1997, apparently from coccidiosis. This appears to be the first record of coccidiosis in Wolves.

Key Words: Wolf, *Canis lupus*, coccidiosis, disease, pathology, protozoa.

Coccidiosis infects a variety of species including such canids as Coyotes (*Canis latrans*) and domestic dogs (*Canis lupus familiaris*) (Pence and Custer 1981). However, to our knowledge the disease has not been reported for Wolves (*Canis lupus*) (Brand et al. 1995), despite the radio-monitoring of many hundreds of Wolves for survival and mortality, including over 600 in the Superior National Forest, Lake County, Minnesota, alone (Mech and Frenzel 1971; Mech 1986, and unpublished; Van Ballenberghe et al. 1975). The present report documents the occurrence of coccidiosis in three Wolf pups from two litters in the Superior National Forest, and the death of at least two of them from this disease.

We live-trapped, weighed, and obtained blood samples (Mech 1974) from four Wolf pups (671, 673, 675, and 699) from one litter in July 1997, and a pup (723) from the litter of an adjacent pack in November 1997 (Table 1). Three of the pups were 31-36% lighter than the expected weight for well-fed wolves of their age and sex (Van Ballenberghe and Mech 1975), and two to four of their six hematological values were aberrant (Table 1). Veterinarians implanted 24.6-gm, mortality-sensing radio-transmitters intra-abdominally in the four littermates, and we released the pups back in their rendezvous sites where caught within 24 hours and monitored their signals at least twice daily. Based on radio-tracking, all these animals moved around similarly, but after 13 and 53 days, two of them died (Table 1). The other two survived at least through 19 November 1998 and 21 October 1999. We live-trapped, weighed, blood-sampled, and radio-collared the fifth pup of our sample (Wolf 723) 14 km east of the other two pups on 4 November 1997, but he never recovered from his capture and handling.

We retrieved Wolf 675 within 24 hours of her death and froze the carcass. Within 8 hours of Wolf 699's death, we found only his transmitter, a length of small intestine, and a fecal bolus. The rest of his remains apparently had been eaten by his pack mates. We froze both specimens. We also froze the carcass of Wolf 723.

On 6 January 1998, the junior author examined all the specimens. Toxicological testing for antimony, bismuth, mercury, and inorganic arsenic (Reisch test) and strychnine and brucine (thin layer chromatogtraphy) were all negative. Electron microscopy of feces (Muneer et al. 1988) from all three Wolves and the fecal sample revealed no virus. Histopathological examination of the intestines showed no evidence of parvoviral enteritis. However, both carcasses had hemorrhagic feces in the large intestines, and the severely autolyzed intestine of the third Wolf (Wolf 699) also had hemorrhage. The intestinal mucosa of both Wolves had many various develop-

TABLE 1. Clinical information about Wolf pups that died from coccidiosis and their littermates that survived, Lake County, Minnesota, 1997.

Wolf Number	Sex	Date Caught	Weight Kg	% Under-Weight[1]	Date Died	Hematology[2] Hct	Hgb	RBC	MCHC	MCV	WBC
671	M	6 August	8.3	41	–	42	13.4	4.4	32	96[2]	22.5[2]
673	M	6 August	8.1	42	–	48[2]	15.7[2]	5.0	33	97[2]	15.0
675	F	7 August	8.3	32	29 September	50[2]	15.5[2]	5.1	31	98[2]	27.9[2]
699	M	6 August	8.9	36	19 August	34[2]	10.8[2]	3.7[2]	32	91	30.4[2]
723[3]	M	4 November	15.5	31	5 November	37	10.0[2]	4.8	27[2]	78	13.7

[1]Compared with data from Van Ballenberghe and Mech (1975).
[2]Outside of standard error of mean values of large sample of Wolf pups from same area, 1969-1972 (Seal et al. 1975).
[3]From pack adjacent to the other Wolves.

mental stages of *Isospora* oocysts in both enterocytes and in the lamina propria.

We concluded that Wolves 675 and 723 died of severe coccidiosis, and that is also the most probable cause of death for Wolf 699. This is the first record that we could find of coccidiosis in Wolves.

Acknowledgments

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Literature Cited

Brand, C. J., M. J. Pybus, W. B. Ballard, and **R. O. Peterson.** 1995. Infectious and parasitic diseases of the gray wolf and their potential effects on wolf populations in North America. Pages 419–429 *in* Ecology and conservation of Wolves in a changing world. *Edited by* L. N. Carbyn, S. H. Fritts, and D. R. Seip. Canadian Circumpolar Institute. Edmonton, Alberta, Canada.

Mech, L. D. 1974. Current techniques in the study of elusive wilderness carnivores. International Congress of Game Biologists 11: 315–322.

Mech, L. D. 1986. Wolf population in the central Superior National Forest, 1967–1985. U.S. Forest Service Research Paper NC-270.

Mech, L. D., and **L. D. Frenzel, Jr.** 1971. Ecological studies of the timber wolf in northeastern Minnesota. U.S. Forest Service Research Paper NC-52.

Muneer, M. E., I. O. Farah, K. A. Pomeroy, S. M. Goyal, and **L. D. Mech.** 1988. Detection of parvovirus in Wolf feces by electron microscopy. Journal of Wildlife Diseases 24: 170–172.

Pence, D. B., and **J. W. Custer.** 1981. Host-parasitic relationships in the wild canidae of North America. II. Pathology of infectious diseases in the genus *Canis*. Pages 760–845 *in* Worldwide Furbearer Conference Proceedings, Volume II. *Edited by* J. A. Chapman and D. Pursley.

Seal, U. S., L. D. Mech, and **V. Van Ballenberghe.** 1975. Blood analyses of wolf pups and their ecological and metabolic interpretation. Journal of Mammalogy 56: 64–75.

Van Ballenberghe, V., A. W. Erickson, and **D. Byman.** 1975. Ecology of the timber wolf in northeastern Minnesota. Wildlife Monograph 43.

Van Ballenberghe, V., and **L. D. Mech.** 1975. Weights, growth, and survival of timber wolf pups in Minnesota. Journal of Mammalogy 56: 44–63.

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Breeding of Steller's Eiders, *Polysticta stelleri*, on the Yukon–Kuskokwim Delta, Alaska

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Flint, Paul L., and Mark P. Herzog. 1999. Breeding of Steller's Eiders, *Polysticta stelleri*, on the Yukon–Kuskokwim Delta, Alaska. Canadian Field-Naturalist 113(2): 306-308.

Historically, an unknown number of Steller's Eiders nested along the outer coastal fringe of the Yukon–Kuskokwim Delta, Alaska, but no nests had been found since 1975. We located six nests from 1991-1998 and we conclude that Steller's Eiders are still a regular breeder at low densities on the Yukon–Kuskokwim Delta.

Key Words: Steller's Eider, *Polysticta stelleri*, threatened, breeding distribution, Alaska.

The Steller's Eider (*Polysticta stelleri*) is a high arctic breeding bird, and little is known of its life history. Surveys of fall molting areas along the Alaska Peninsula suggested an overall decline in numbers, and the number of birds breeding in Alaska may have also declined (Anonymous 1997). From these trends the Alaska breeding population of Steller's Eiders was listed as *Threatened* under the provisions of the U.S. Endangered Species Act (Anonymous 1997). Historically, within Alaska, Steller's Eiders were only known to have nested regularly on the Yukon–Kuskokwim Delta (Y–K Delta) and along the Arctic Coastal Plain near Barrow (Kertell 1991). Kertell (1991) summarized the population status of Steller's Eiders breeding on the Y–K Delta and noted that no nests had been discovered since 1975 during nest searches conducted for other species. Kertell (1991) concluded that Steller's Eiders were "apparently extinct" as a breeding bird on the Y–K Delta. In this paper we present recent observations of breeding by Steller's Eiders on the Y–K Delta and expand on Kertell's (1991) discussion of possible causes for the historic decline in breeding numbers.

Study Area and Methods

The data we present here were collected during spring migration and nesting periods in conjunction with two separate studies on nearly adjacent study areas from 1991–1998 (Figure 1). The first site, referred to as Hock Slough (HS), is along the lower Kashunuk River about 5 km inland from the Bering Sea coast (61°20′ N, 165°35′ W). Studies at HS focused on breeding ecology and survival of Northern Pintails (*Anas acuta*) and Spectacled Eiders (*Somateria fischeri*). For these studies approximately 27 km^2 were searched each year for duck nests and nest detection probability was subjectively estimated at > 85% (Flint and Grand 1996; Grand and Flint 1997). The second study site, referred to as Tutakoke River (TR), is south of HS and is located within 2 km of the Bering Sea coast (61°15′ N, 165°37′ W). Ongoing studies at TR focus on population biology and life histories of Black Brant (*Branta bernicla nigricans*) (Sedinger et al. 1995, 1997, 1998). At TR areas were searched for brant nests at three levels of intensity. Approximately 0.4 km^2 was searched at sufficient intensity to detect every waterfowl nest regardless of success or failure. An additional 3.6 km^2 were searched at medium intensity and nest detection probability was subjectively estimated at 85%. Also 2.5 km^2 were searched at low intensity and nest detection probability was less than 50%.

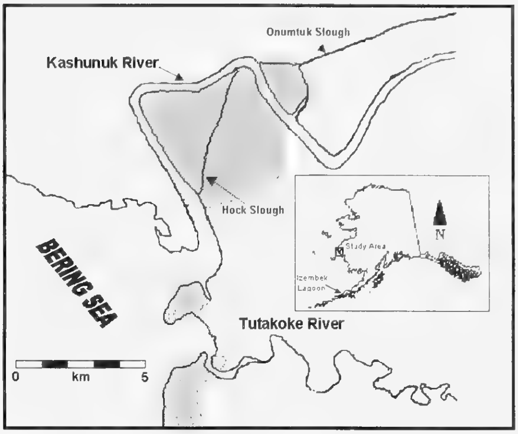

FIGURE 1. Location of study areas on the Yukon-Kuskokwim Delta, Alaska. Shaded areas indicate areas searched in 1991-1998. Compare with Figure 4 in Kertell (1991).

Results

Observations of Steller's Eiders from 1991 to 1998.

1991-1993 No Steller's Eiders were observed.

1994 A single pair of Steller's Eiders was observed along the Kashunuk River near HS. A nest located on 7 June 1994 contained five fresh eggs. The final clutch size was seven eggs. Assuming one egg laid per day, this nest was initiated on 3 June. The nest was destroyed by gulls (*Larus* spp.) or jaegers (*Stercorarius* spp.) between 20 and 27 June. The female associated with this nest was not banded.

1995 No Steller's Eiders were observed.

1996 A single pair was observed by staff of the TR camp approximately 2 km south of TR. A single nest containing six eggs was located on 28 May. No information on egg development or final status of nest was recorded. Neither bird was banded.

1997 Two pairs were observed by staff of the TR camp for approximately two weeks in late May and early June. One pair was approximately 2 km south of TR. The second pair was seen 1 km northeast of the TR camp. Band status of these birds was not determined. The general area where one pair was observed most frequently was near the 1996 Steller's Eider nest (see above). No nests were located, but high Arctic Fox (*Alopex lagopus*) predation occurred in the vicinity and it was likely that any nests would have been destroyed prior to location.

A pair of Steller's Eiders was observed along the Kashunuk River in early June by staff of the HS field camp. A nest containing six eggs was located on 15 June. This nest was initiated approximately 8 June based on egg candling estimates of embryonic development (Weller 1956) at the time of discovery. The female, observed to be banded when flushed from the nest, was captured with a mist net on 27 June to determine the band number. This bird was banded on 7 September 1994 at Izembek Lagoon (55°15′ N, 163°00′ W, Figure 1). The nest was successful.

1998 Two pairs were observed by the staff of the TR camp in early June and two nests were located. The first nest containing four eggs was found 1 km west of TR on 10 June. The second nest was found 4 km southeast of the TR field camp on 11 June. The number of eggs in the second nest was not recorded. None of the birds were banded. Both nests were destroyed by predators before hatch. A pair of Steller's Eiders was observed by staff of the HS camp in early June. A single nest was located on 16 June containing seven fresh eggs. We estimated the nest was initiated on 10 June. The female, observed to be banded at the time of nest discovery, was trapped on 23 June using a bow-type nest trap. This was the same female that nested on the HS study area in 1997 (see above). Distance between nest locations across years was 123 meters based on GPS coordinates recorded at times of nest discovery. The nest was successful; however, gulls or jaegers had removed at least one egg prior to hatch based on final count of egg membranes.

Discussion

Our observations indicated that Steller's Eiders are not extinct as breeding birds on the Y–K Delta, and they are regular breeders at very low densities. There are several possible explanations for the lack of nests found during the period from 1976-1994. As suggested by Kertell (1991), Steller's Eiders may indeed have been absent as breeding birds during this period, our recent observations were thus the result of re-colonization of available habitat by dispersing pairs. Alternatively, Steller's Eiders may have been present at low densities, but their nests were not detected or were misidentified as another species. Overall, nesting success for ducks along the outer coastal fringe of the Y–K Delta is quite low in some years (Flint and Grand 1996; Grand and Flint 1997). As most duck nests were located by flushing incubating females, detection of unsuccessful nests was likely very low. Additionally, a wide variety of duck species nest in areas where Steller's Eider nests have been found, and Steller's Eider nests could easily have been confused with Oldsquaw (*Clangula hyemalis*) or Greater Scaup (*Aythya marila*) based on color of down. Finally, only a small percentage (i.e., < 5%) of potential Steller's Eider habitat as defined by Kertell (1991) (i.e., 2300 km^2) was searched in any one year. Thus, we believe that it is likely that Steller's Eiders were never absent as breeders on the Y–K Delta, and that their nests were not detected because they occurred in areas not searched, their nests were destroyed prior to areas being searched, or their nests were misidentified.

Finally, Kertell (1991) listed possible causes for the apparent population decline of Steller's Eiders breeding on the Y–K Delta. We propose an additional potential explanation based on recent results for other species. Both recent and historic nests of Steller's Eiders were found in habitats frequently used by nesting Spectacled Eiders (Kertell 1991; Grand and Flint 1997). Recent studies identified lead poisoning as an important source of mortality for breeding Spectacled Eiders (Franson et al. 1995; Flint and Grand 1997; Flint et al. 1997; Franson et al. 1998; Grand et al. 1998). If both Spectacled and Steller's eiders used similar habitats for feeding, then lead poisoning may have contributed to the long term population decline of Steller's Eiders breeding on the Y–K Delta. Further, the slow settlement rate of lead shot in these habitats suggests that lead poisoning may continue to be an obstacle to Steller's Eider population recovery on the Y–K Delta (Flint 1998).

Acknowledgments

We thank the numerous technicians (too many to list here) that assisted with nest searches on both study areas. D. Derksen, M. Petersen and J. Sedinger provided helpful comments on an earlier draft of this manuscript.

Literature Cited

Anonymous. 1997. Endangered and threatened wildlife and plants: Threatened status for the Alaska breeding population of the Steller's Eider. Federal Register [Washington, D.C.] 62(112): 31748–31757.

Flint, P. L. 1998. Settlement rate of lead shot in tundra wetlands. Journal of Wildlife Management 62: 1099–1102.

Flint, P. L., and **J. B. Grand.** 1996. Nesting success of Northern Pintails on the Yukon–Kuskokwim Delta, Alaska. Condor 98: 55–61.

Flint, P. L., and **J. B. Grand.** 1997. Survival of adult female and juvenile spectacled eiders during brood rearing. Journal of Wildlife Management 61: 218–222.

Flint, P. L., M. R. Petersen, and **J. B. Grand.** 1997. Exposure of Spectacled Eiders and other diving ducks to lead in western Alaska. Canadian Journal of Zoology 75: 439–443.

Franson, J. C., M. R. Petersen, C. U. Meteyer, and **M. R. Smith.** 1995. Lead poisoning of spectacled eiders (*Somateria fischeri*) and of a common eider (*Somateria mollissima*) in Alaska. Journal of Wildlife Diseases 31: 268–371.

Franson, J. C., M. R. Petersen, L. C. Creekmore, P. L. Flint, and **M. R. Smith.** 1998. Blood lead concentrations of Spectacled Eiders near the Kashunuk River, Yukon Delta National Wildlife Refuge, Alaska. Ecotoxicology 7: 1–7.

Grand, J. B. and **P. L. Flint.** 1997. Productivity of nesting Spectacled Eiders on the lower Kashunuk River, Alaska. Condor 100: 926–932.

Grand, J. B., P. L. Flint, M. R. Petersen, and **T. L. Moran.** 1998. Effect of lead poisoning on spectacled eider survival rates. Journal of Wildlife Management 62: 1103–1109.

Kertell, K. 1991. Disappearance of the Steller's eider from the Yukon–Kuskokwim Delta, Alaska. Arctic 44: 177–187.

Sedinger, J. S., P. L. Flint, and **M. S. Lindberg.** 1995. Environmental influence on life-history traits: Growth, survival and fecundity in Black Brant (*Branta bernicla*). Ecology 76: 2404–2414.

Sedinger, J. S., M. S. Lindberg, B. T. Person, M. P. Herzog, and **P. L. Flint.** 1998. Density-dependent effects on growth, body size, and clutch size in Black Brant. Auk 115: 613–620.

Sedinger, J. S., M. S. Lindberg, M. W. Eichholtz, and **N. D. Chelgren.** 1997. Influence of hatch date versus maternal and genetic effects on growth of Black Brant goslings. Auk 114: 129–132.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20: 111–113.

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Range Extension of Spring Peepers, *Pseudacris crucifer*, in Labrador

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Bergman, Carita M. 1999. Range extension of Spring Peepers, *Pseudacris crucifer*, in Labrador. Canadian Field-Naturalist 113(2): 309–310.

Calls of Spring Peepers, *Pseudacris crucifer*, were recorded on 15 June 1998 in a marsh near Goose Bay, Labrador. The occurrence of this species has never been confirmed in Labrador previously.

Key Words: Spring Peeper, *Pseudacris crucifer*, amphibian, range extension, Labrador.

For the Québec portion of the Québec-Labrador Peninsula, Bider and Matte (1996) mapped the range of the Spring Peeper, *Pseudacris crucifer*, south of 51°N latitude, and as far east as Sept-Iles and the Gaspé Peninsula. They also reported two occurrences just east of James Bay at almost 54°N. In addition to these confirmed records, there are two unsubstantiated reports of Spring Peepers in Labrador north of 53°N: a sight record near Menihek Lake in western Labrador (Bleakney 1954, 1958), and an auditory record at Thomas Brook (known locally as Toma's Brook or on published maps as Upper Brook) in the lower Churchill River drainage (Maunder 1983) (Figure 1). Because these two reports lacked voucher specimens, Maunder (1983) suggested that Labrador populations of Spring Peepers should be treated as hypothetical. However, on a recent excursion near Goose Bay, Labrador, I was able to document the calls of Spring Peepers on tape.

During a canoe trip down the Peters and Goose rivers near Goose Bay, Labrador (start point: 53°20′ N 60°47′ W; end point: 53°24′ N 60°26′ W) on 14 June 1998, I heard scattered calls of single Spring Peepers through the day. At approximately 22:15, I heard a large chorus of Spring Peepers calling in a marshy area adjacent to the Goose River at 53°23′N 60°29′W. The following evening, 15 June 1998, I drove to a small marsh located at 53°22′ N 60°30′ W on the south bank of the Goose River, where I recorded two Spring Peepers calling between 23:00 and midnight. Duration of peeping episodes ranged approximately from 30 seconds up to three minutes, and began with a single calling individual, at times answered by a second midway through the episode. Calling rates ranged approximately from 60 to 69 calls per minute. Ambient sound was dominated by trills of one to several American Toads (*Bufo americanus*) and abundant mosquitoes. Cassette tapes of the recorded calls have been deposited with the Natural History Unit of the Newfoundland Museum in St. John's, with the Goose Bay Wildlife Division of the Newfoundland and Labrador Department of Forest Resources and Agrifoods, and with the Canadian Field-Naturalist.

Daytime reconnaissance of the area where the calls were recorded revealed that the habitat was a small marsh approximately 0.5 hectares in size. The marsh was dominated by a thick mat of *Sphagnum* around the periphery, becoming progressively wetter towards the centre. Scattered floating mats of *Sphagnum* and standing water covered approximately one-half of the area. In the centre of the marsh, *Carex* spp. were growing through the water in abundance. Interestingly, the area containing the marsh was once mature spruce forest that had been logged in 1976 (John Thomas, District Forester, personal communication), and thus contained many old tree stumps protruding from the water. Second-growth forest bordering the south edge of the marsh was characterized by Black Spruce (*Picea mariana*), Larch (*Larix laricina*) and Mountain Alder (*Alnus viridis crispa*), while a sandy ridge on the north edge contained a mix of White Birch (*Betula papyrifera*), Balsam Fir (*Abies balsamea*), Mountain Alder and White Spruce (*P. glauca*), with Labrador Tea (*Rhododendron groenlandicum*) and Sheep Laurel (*Kalmia angustifolia*) dominating the understory.

This is the first species of the genus *Pseudacris* to be confirmed in Labrador, and joins four other anurans that are currently confirmed in Labrador: the American Toad, the Leopard Frog (*Rana pipiens*), the Mink Frog (*R. septentrionalis*), and the Wood Frog (*R. sylvatica*) (Maunder 1983). The closest confirmed report of Spring Peepers at a latitude similar to that of Goose Bay is near Lac Nathalie, Québec, over 1000 km to the west (MacCulloch and Bider 1975; Bider and Matte 1996). The closest confirmed record overall is a report near Sept-Iles, Québec, 500 km to the southwest (Bider and Matte 1996) (Figure 1). The confirmation of Spring Peepers in Labrador lends credence to the previous unsubstantiated reports from Menihek Lake (Bleakney 1954, 1958) and Thomas Brook (Maunder 1983). However, it remains uncertain whether Labrador populations are continuous with those in Québec. The Lower Churchill River/Goose Bay area has an exceptionally warm microclimate, and may harbour disjunct populations of more southern species of

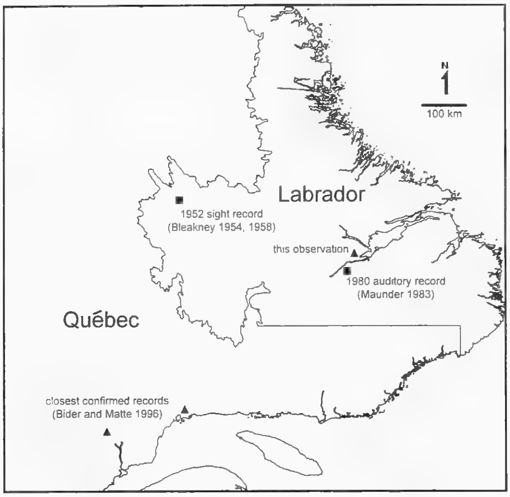

FIGURE 1. A summary of Spring Peeper records in Labrador and nearby Québec. Further description of the records is given in the text. Triangles indicate confirmed occurrences.

plants and animals (John Maunder, Newfoundland Museum Curator, personal communication).

Amphibians are thought to be experiencing a global decline (Barinaga 1990; Blaustein and Wake 1990), and many monitoring programs are currently being developed to monitor sensitive populations (Heyer et al. 1994). Although Spring Peeper populations in Québec are believed to have remained stable in recent times (Weller and Green 1997), this could only be established reliably if extensive monitoring programs were established throughout their northern range. The Labrador population of Spring Peepers is located on the extreme northeastern edge of the species' range; thus, it might be expected to be affected early by any climatic factors leading to a general decline in numbers or contraction of range. As yet, Newfoundland is one of the few provinces that lacks an amphibian monitoring program. However, the Newfoundland Museum has compiled historic and contemporary records (Maunder 1983, 1997), and plans for more extensive surveys are underway. John Thomas, a forester with the Department of Forest Resources & Agrifoods in Goose Bay, has monitored amphibian calling routes located along roads in the Goose Bay area for the previous four years. Even though Spring Peepers are now known to inhabit the Goose Bay area, a much more intensive survey of southern Labrador is still needed to establish whether this is an isolated population, or is continuous with known southern populations.

Acknowledgments

I thank F. R. Cook (Curator Emeritus, Research Associate, Canadian Museum of Nature), J. E. Maunder (Newfoundland Museum, St. John's, Newfoundland), F. W. Schueler (Biological Checklist of the Kemptville Creek Drainage Basin, and Research Associate, Canadian Museum of Nature), and D. and C. Seburn (Seburn Associates, Oxford Mills, Ontario) for listening to my call recordings, Julie Green, Jane McGillivray, Frank Phillips and John Thomas for logistical support, and last-but-not-least, France Paquet for her able assistance in the stern. J. E. Maunder, D. Seburn, and one anonymous referee provided editorial comments on earlier drafts of this manuscript.

Literature Cited

Barinaga, M. 1990. Where have all the froggies gone? Science 247: 1033–1034.

Bider, J. R., and **S. Matte.** 1996. The atlas of amphibians and reptiles of Québec. St. Lawrence Valley Natural History Society, Sainte-Anne-de-Bellevue, Québec and Ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, Québec. 106 pages.

Blaustein, A. R., and **D. B. Wake.** 1990. Declining amphibian populations: a global phenomenon? Trends in Ecology and Evolution 5: 203–204.

Bleakney, J. S. 1954. Range extensions of amphibians in eastern Canada. Canadian Field-Naturalist 68: 165–171.

Bleakney, J. S. 1958. A zoogeographical study of the amphibians and reptiles of eastern Canada. National Museum of Canada Bulletin 155. 119 pages.

Maunder, J. E. 1983. Amphibians of the province of Newfoundland. Canadian Field-Naturalist 97: 33–46.

Maunder, J. E. 1997. Amphibians of Newfoundland and Labrador: status changes since 1983. Herpetological Conservation 1: 93–99.

Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and **M. S. Foster.** 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institution Press, Washington. 364 pages.

Weller, W. F., and **D. M. Green.** 1997. Checklist and current status of Canadian amphibians. Herpetological Conservation 1: 309–328.

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Addendum:

In recent communication with two biology teachers and conservationists, Betty Anne and Sam Fequet of Goose Bay, Labrador, the author was informed that local school children have recently (in the last one to six years) observed "weensy tree frogs" that they had found in trees and bushes, allegedly with "sticky feet" and consistent in colour with Spring Peepers. Locations where they were found were near Gosling and Alexander Lakes, adjacent to the town limits (the unfortunate amphibians were subsequently used as target practice). Future searches would benefit from collaboration with local schools in the Goose Bay area.

News and Comment

Notices

The 121st Annual Business Meeting of The Ottawa Field-Naturalists' Club: 11 January 2000

The 121st Annual Business Meeting of the Ottawa Field-Naturalists' Club will be held in the auditorium of the Canadian Museum of Nature, McLeod and Metcalfe streets, Ottawa, on Tuesday 11 January 2000 at 7:30 p.m. (19:30 h).

GARY MCNULTY
Recording Secretary

Call for Nominations: Ottawa Field-Naturalists' Club 1999 Awards

Nominations are requested from members of The Ottawa Field-Naturalists' Club for the following: Honorary Membership, Member of the Year, George McGee Service Award Citation, Conservation, and the Anne Hanes Natural History Award. Descriptions of these awards appeared in *The Canadian Field-Naturalist* 96(3): 367 (1982). The Service Award was renamed the George McGee Service Award in 1993 [see *The Canadian Field-Naturalist* 108(2): 243-244 (1994)]. With the exception of nominations for Honorary Member, all nominees must be members in good standing. Deadline for nominations is 1 December 1999.

STEPHEN DARBYSHIRE
Chair, Awards Committee

Call for Nominations: The Ottawa Field-Naturalists' Club 2000 Council

Candidates for Council may be nominated by any member of The Ottawa Field-Naturalists' Club. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee. Some relevant background information on the nominee should also be provided. Deadline for nominations is 15 November 1999.

FRANK POPE
Chair, Nominating Committee

Alberta Wildlife Status Reports: numbers 12 to 18

The Fisheries and Wildlife Management Division of the Alberta Natural Resource Status and Assessment Branch, Alberta Environmental Protection, has released (March - October 1998) status reports numbers 12 to 17 and announced number 18 in preparation as of January 1999. The Series Editor (12) and Senior Editor (remainder) is David R. C. Prescott; the Series Editor for remainder is Isabelle M. Richardson, and the illustrations are by Brian Huffman.

For a listing of numbers 1-11 in the series, see *The Canadian Field-Naturalist* 112(1): 169, January-March 1998.

The new reports are:

12. Status of the Canadian Toad (*Bufo hemiophrys*) in Alberta, by Ian M. Hamilton, Joann L. Skilnick, Howard Troughton, Anthony P. Russell, and G. Lawrence Powell. 30 pages.
13. Status of the Sage Grouse (*Centrocercus urophasianus urophasianus*) In Alberta, by Cameron L. Aldridge. 23 pages.
14. Status of the Great Plains Toad (*Bufo cognatus*) in Alberta, by Janice D. James. 26 pages.
15. Status of the Plains Hognose Snake (*Heterodon nasicus nascicus*) in Alberta, by Jonathan Wright and Andrew Didiuk. 26 pages.
16. Status of the Long-billed Curlew (*Numenius americanus*) in Alberta, by Dorothy P. Hill. 20 pages.
17. Status of the Columbian Spotted Frog (*Rana luteiventris*) in Alberta, by Janice D. James. 21 pages.
18. Status of the Ferruginous Hawk (*Buteo regalis*) in Alberta, by Josef K. Schmutz. In preparation.

For copies contact: Information Centre - Publications, Alberta Environmental Protection, Natural Resources Service, Main Floor, Bramalea Building, 9920 - 108 Street, Edmonton, Alberta T5K 2M4, Canada (telephone: (403) 422-2079), OR Information Service, Alberta Protection, #100, 3115 - 12 Street NE, Calgary, Alberta T2E 7J2, Canada (telephone: (403) 297-3362).

Global Biodiversity: Winter 1998/Spring 1999/ Final issues?

Volume 8, Number 3, Winter 1998, has one major feature: "Sameness and silence: Language extinctions and the dawning of a biocultural approach to diversity" ("The two great realms of living diversity are cultural and biological, and today both are in peril") by David Harmon, Executive Director, The George Wright Society, and Co-Founder, Terralingua. It also includes 8 DEPARTMENTS: Editors Notebook (Climate warming), Portrait of Biodiversity

(Black Howler Monkey); Biodiversity News (Birds measure Briton's health; Consumer boycotts work; Swedes spend more on environment; Efficient energy means saving money; Coelacanth news; Worldwide deaths due to pollution); Forum (Intellectual property rights and the WTO); Successes and Initiatives (Unlikely allies help endangered species; Plant naming goes on-line); Cyberdiversity; Biodiversity Meetings; Book Reviews; The Last Word (Keeping up to date with nature through bioinformatics: Larry Speers, Coordinator, CanBll - Canadian Biodiversity Information Initiative, Canadian Museum of Nature).

Volume 8, Number 4, Spring 1999, is announced as the last to be published by the Canadian Museum of Nature, Ottawa, of this journal which began in March 1991 (see initial notice in *The Canadian Field-Naturalist* 105(1): 127). The final number contains a FEATURE article — Measuring the harm and benefit: The biodiversity friendliness of *Cannabis sativa* (Suzanne Montford and Ernst Small); a FORUM contribution — Conserving the gray wolf in Ontario: a different view (John B. Theberge and Mary T. Theberge) [on the need to conserve the wolf population at Algonquin Park which may actually be a new species of mammal for Canada: recent studies indicate it is allied to the southern "Red Wolf, *Canis rufus*" and both may be classified as *Canis lycaon*, distinguishable from the northern *Canis lupus nubilus* north of Algonquin Park and in eastern Quebec]. In addition there are eight DEPARTMENTS: Editor's Notebook (The cooperative gene); Portrait of Biodiversity (*Pileus mexicanus*, the wild papaya); Biodiversity News (Concern high but environmental myths intact; Old-growth forests get help from the private sector; Canadian fresh water resources at risk; Rare coral shows cancer-fighting promise...); Cyberdiversity; Biodiversity Resources; Book Reviews; The Last Word (The panorama of life) in which Editor-in-Chief and Researcher Emeritus, Don McAllister, who founded the publication and was its editor and driving force throughout its existence, comments on its extinction, noting that despite 2000 subscribers the Museum administration has decided that it can no longer support it financially. It was the last of that institution's series publications, others terminated in the past 30 years were a scientific *Bulletin* series, several *Publications in* [Zoology, Botany, Natural History, etc] series, *Natural History Notes*, *Syllogeous*, and the more popular-orientated *Neotoma* and *Biome*.

Global Biodiversity was edited by Don E. McAllister, and its last Managing Editor was Judy Redpath. It was published quarterly by the Canadian Museum of Nature, P. O. Box 3443, Postal Station D, Ottawa, Ontario K1P 6P4, Canada. For further information access URL: http://www.nature.ca

Recovery Plans for Nationally Endangered Wildlife (RENEW) in Canada: RENEW Reports 15 to 18

RENEW, a strategy to rescue wildlife species at risk of extinction (in Canada) and to prevent other species from becoming at risk, was endorsed by the Wildlife Ministers' Council in 1988. The RENEW committee establishes a "recovery team" of experts for each population of terrestrial mammal, bird, reptile, amphibian, that has been designated as extirpated, endangered, or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This team then produces a recovery plan which then becomes the basis for a recovery program carried out by the responsible governments in cooperation with universities, businesses, and private citizens. *The Canadian Field-Naturalist* 109(1): 124, listed RENEW reports numbers 1 to 11; 109(2): 266, listed numbers 12 and 13, and 110(2): 357, listed number 14.

Additional RENEW Reports now available from Recovery of Nationally Endangered Wildlife, Ottawa, Ontario K1A 0H3 are:

15. National Recovery Plan for the Swift Fox April 1996.
16. National Recovery Plan for Blanchard's Cricket Frog March 1997
17. National Recovery Plan for Henslow's Sparrow August 1997
18. National Recovery plan for Blanding's Turtle (*Emydoidea blandingii*) Nova Scotia population January 1999.

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF): number 31

Number 31, February 1999, contains: Dead Newts in Peneda Gues, Portugal (Elsa Froufe, J. W. Arntzen and Aramando Loureiro; Amphibians in Michoacan, Mexico (Javier Alvardso Diaz; Amphibians & *Crassula helmsii* (Will Watson); New Amphibian Parasites from Sri Lanka; Education Working Group Report (Karen S. Graham); Experts Seek Consensus on Causes of Amphibian Abnormalities (James K. Reaser); DAPTF Rapid Response Fund; DAPTF Board Meeting 1999; Froglog Shorts; Publications of Interest.

Froglog is available from Editor John W. Wilkinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk

Marine Turtle Newsletter: number 83

Number 83, January 1999, contains: Guest Editorials: The WTO Shrimp/Turtle Case (Deborah Crouse); Common Sense Conservation (Roderic Mast); Articles: Generetic Consequences of Costal Development - the Sea Turtle Rookeries at X'cacel, Mexico (Dandra E. Encalada, Julio C. Zurita, & Brian W. Browen); An update on the Mortality of the Olive Ridley Sea Turtles in Orissa, India (Bivash Pandav & B.C. Choudhury); Decline of Marine Turtle Nesting

Populations In Pakistan (Fehmida F. Asrar); Announcements, Recent Publications, and Acknowledgements.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, UK; e-mail MTN@swan.ac.uk; Fax +44 1792 295447.

Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; Fax + 1 978 840 8184. MTN website is: <http://www.seaturtle.org/mtn/>

Sea Wind: Bulletin of Ocean Voice International: 12(4)

Volume 12, number 4, October-December 1998 contains features — See the Light: Save Western Canada's lighthouses — Bottom trawling: The world's leading disturbance of the seafloor — Bill Reid: Haida carver, sculptor, jeweller, poet and writer, 1920-1998 — ITQs, the latest fishery management disaster? — Underea cable biters: What are they? — The distribution of coral reef fish biodiversity: The climate-biodiversity connection, and departments — Sea News — On the Net — New Publications.

Sea Wind is available though membership in Ocean Voice International P. O. Box 37026, 3332 McCarthy Road, Ottawa, Ontario K1V 0W0, Canada; e-mail: mcall@superaje.com; World-Wide Web site:<http://www.ovi.ca>.

Rana-Saura: Amphibian population monitoring program; Atlas of amphibians and reptiles of Quebec: 5(2)

Volume 5, Number 2, March 1999 contains: Quite a special year! (most amphibian species active in the spring of 1998 up to three weeks in advance of their usual dates) — The amphibian populations monitoring program (coordinator's year end comments; road surveys, reproduction sites, urban sprawl, malformation reporting; participants) — The atlas of amphibians and reptiles of Quebec (the 12th year; over 1800 observations for 1998, a second look at 1997 - additional records of rare species — the (long-term) importance of the data) — updates on new stories and web sites.

For more information contact David Rodrique, Saint Lawrence Valley Natural History Society, 21125 ch. Ste-Marie, Ste-Anne-de-Bellevue, Quebec H9X 3L2; e-mail ecomus@total.net.

Recovery: An Endangered Species Newsletter: Fall 1998

The fall 1998 issue, coordinated by the Canadian Wildlife Service and edited and designed by West Hawk Associates, features Scientists seek causes of amphibian decline (David M. Green) — Special Report: A 'Made in Canada' approach (The Species at Risk Working Group: a synopsis of a documnent *Conserving species at risk and vulnerable ecosystems: Proposals for legislation and programs* endorsed by the Canadian Wildlife Federation, The Canadian Nature Federation, Sierra Club of Canada, and unnameed representative organizations of the forestry, mining, and agriculture industries) — Toward an improved recovery process (Kent A. Prior) — COSEWIC to assess new criteria (Therese Aniskowicz-Fowler) — Fishers and satellites key to marine mammal research (Cathy Merriman) — Renew Hightlights: Surprise find of Acadian Flycatchers (Mike Cadman) — Renew Update — Captive-breeding central to marmot recovery — Featured Species: The plight of the Banff Springs Snail.

Recovery is available from the Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada or is accessible on the net at <www.ec.gc.ca/cws-scf/es/recovery/eng/index.html>

XVI International Botanical Congress: August 1999

The world's largest gathering of plant scientists will be held 1-7 August 1999 at *America's Center*, the convention centre of St. Louis, Missouri, with an expected attendance of more than 5000 scientists from 100 countries. It will feature a record 200 symposia with some 1500 oral presentations and 4000 poster sessions, 20 interdisciplinary keynote symposia presenting particularly challenging perspectives on current issues of broad interest, including the conservation of endangered plants, ancient fossils and their significance for human, plant, and animal evolution, feeding the world, and science and society.

Sessions of the International Congress are held only once every six years. In this century it was held first in Paris in 1900, and most recently in Tokyo in 1993; the last in the United States was in Seattle in 1969. The XVI IBC President is Peter H. Raven, Missouri Botanical Garden, Vice-presidents are John McNeill, Royal Ontario Museum, and Jose Sarukhan, Universidad Nacional Autonoma de Mexico; and the Secretary-General is Peter C. Hoch, Missouri Botanical Garden.

For more background and up-to-date information see the XVI IBC website: www.ibc99.org

Ontario Natural Heritage Information Centre Newsletter: 5(1)

Volume 5 Number 1, Spring 1999, contains: Data Maintenance and Gap Analysis Project for Southern Ontario; Rare Vegetation of Ontario: Tallgrass Prairie and Savannah; Vegetation Community Database Update; The Evolution of a Prairie Landscape Over Time In Raleigh Township, Kent County; Ontario's Globally Rare Plants; 1998 Botanical Highlights; NHIC Enters its Sixth Year; ABI [Association for Biodiversity Information] - Canada; New NHIC Plant Lists Now Available; Committee on the Status of Species at Risk In Ontario (COSSARO); NHIC Assists with First Annual Peterborough County Natural History Summary; NHIC to Assist with National Ranking of Canada's Rare Vascular Plants; Hart's-tongue Fern Status Report; Interesting Amphibian and Reptile Websites [an annotated listing of 13 Canadian and 4 northern United States: Minnesota, New York, Ohio, Wisconsin] sites; Publications; Information Requests; Renewed Subscriptions; NHIC Staff List.

The Newsletter is edited by Peter J. Sorrill. Copies can be obtained from the Natural Heritage Information Centre, P. O. Box 700, Peterborough, Ontario K9J 8M5; the web page is http://www.mnr.gov.on.ca/MNR/nhic/nhic.html

FRANCIS R. COOK

Thomas Henry Manning Bequest to The Ottawa Field-Naturalists' Club

On 8 November 1998, long-standing member Thomas Henry Manning died at the age of 86, after 57 years of membership in the Ottawa Field-Naturalists' Club. In 1949, Mr. Manning took out life membership and in 1982 was made an honorary member.

In letters from the lawyers for his estate we were informed that the OFNC had been bequeathed a substantial sum of money. In early 1999 the Club's President, Dave Moore, and the Business Manager, Bill Cody, went to the offices of Low, Murchison to sign final papers and a few days later a cheque for $100 000.00 was delivered to Mr. Cody.

Because of the size of the bequest, the money was put immediately into the Club's savings account pending a final decision on the best use for the funds. Council has been asked to disseminate this information to the various committees, and by the way of this letter, the general membership.

It is hoped that the money can be used in a way that would reflect the man who had spent many years in the Arctic mapping and assembling zoological collections, now with the Canadian Museum of Nature and the Royal Ontario Museum. As an example, Mr. Manning recently gave $1 million to Cambridge University to go toward a new library at the Scott Polar Research Institute. It should be noted that the bequest has no constraints or directions for the use of the money.

Recommendations from committees and council will be gathered and a final use for money will be made in a timely, but not hasty, manner. In the interim, and on the advice of the Finance Committee, the money may be moved to a different type of account which will generate greater revenues for the Club.

Our belated thanks go out to this generous man, and our condolences to his friends and family.

DAVE MOORE

President, Ottawa Field-Naturalists' Club
10 May 1999

Editor's Report for *The Canadian Field-Naturalist* Volume 112 (1998)

Manuscripts (excluding book reviews, notices, club or journal reports) submitted to *The Canadian Field-Naturalist* totalled 113 in 1998, a decrease of 6 from 1997. By 31 December, of 92 for which reviewing was completed, 7 were rejected, 24 returned for minor to major revision were still with their authors, and 61 had been revised and returned and accepted. Seventeen of these have or will appear in volume 112, numbers 3 (1) and 4 (16); 44 in volume 113, numbers 1 (2), 2 (28) and 3 (14). Also accepted this year were 25 revisions of papers first submitted in 1996 (2) and 1997 (23). All but two were included in volume 112, leaving two for 113 (both in number 2). Totals for 1997 are still also incomplete but of the 119 total manuscripts submitted that year, 93 have now been accepted (78%); 10 of 26 others still might be accepted if adaquately revised. The special issue on the history of the Canadian Wildlife Service 1947-1997 by Alexander Burnett commissioned by the CWS was accepted for 113(1) in 1999 and I owe special thanks to Pat Logan of the CWS for her work in assuring this manuscript its 69 photos to be included were submitted in 1998, as well as the listing of selected CWS publications prepared by A. J. Erskine to accompany the history.

Totals for circulation to members of the Ottawa Field-Naturalists' Club and individual and institutional subscribers to *The Canadian Field-Naturalist* in 1997 together with those of 1996 are given in Table 1.

Issue mailing dates for volume 111 were: (1) 7 March 1998, (2) 17 July 1998, (3) 9 December 1998, and (4) 27 March 1999. Volume 112 totalled 790 pages; the largest single issue (4) was 216 pages.

The number of articles and notes in volume 112 is summarized in Table 2 by topic; totals for Book Reviews and New Titles are in Table 3, and the distribution content among issues in Table 4.

M.O.M. Printers, 300 Parkdale Avenue, Ottawa, set and printed the journal and special thanks are due Emile Holst, and to Yolland, Cecilia, Bruce and all the others of the MOM staff whose efforts make each issue possible. Wanda J. Cook proof-read the galleys for the volume. Bill Cody continued as Business Manager and again oversaw the compilation and proof-read the Index for volume 111 which was diligently prepared by Leslie Durocher. Wilson Eedy continued as Book-Review Editor. George La Roi nominally retired as as Coordinator of the Biological Flora of Canada but is preparing a summary of this series.

Suitable manuscripts submitted to the Canadian Field-Naturalist are normally reviewed by at least one associate editor and one (or more) additional reviewer(s) to provide a balance of opinions. Virtually all manuscripts eventually accepted are revised by the authors after review. I am indebted to all who returned reviews in 1998 (with number, if more than one, in parenthesis):

Associate Editors — Mammalogy: William O. Pruitt, Jr., Department of Zoology, University of Manitoba, Winnipeg (29); Warren B. Ballard, Department of Range, Wildlife and Fisheries Management, Texas Tech University, Lubbock, Texas (20); Ornithology: Anthony J. Erskine, Canadian Wildlife Service, Sackville, New Brunswick (32); W. Earl Godfrey, Canadian Museum of Nature, Ottawa, Ontario (3); Fish and Marine Mammals: Robert R. Campbell, Woodlawn, Ontario (5); Ichthyology: Brian W. Coad, Canadian Museum of Nature (7);

TABLE 1. The 1998 circulation of The Canadian Field-Naturalist (1997 in parenthesis). Membership totals from Annual Report of the Ottawa Field-Naturalists' Club, January 1999; subscription totals compiled by W. J. Cody. Forty percent of membership dues and 100% of subscriptions go to production of *The Canadian Field-Naturalist*. Members vote on Club affairs, individual subscribers and institutions do not.

	Canada	USA	Other	Totals
Memberships				
Family & Individual	938 (939)	30 (31)	5 (5)	973 (975)
Subscriptions				
Individuals	186 (173)	61 (55)	5 (5)	252 (233)
Institutions	181 (186)	258 (257)	41 (43)	480 (486)
Totals	369 (359)	319 (312)	46 (48)	732 (719)
TOTALS	1305 (1298)	349 (344)	51 (53)	1705 (1695)

Note: 20 countries are included under "Other" (outside Canada and United States): Institutions: Australia 2, Austria 1, Belgium 1, Brazil 1, Denmark 1, England 8 (including Northern Ireland 1), Finland 5, France 2, Germany 3, Japan 2, Netherlands 2, New Zealand 1, Norway 4, Poland 1, Russia 1, South Africa 1, Spain 2, Sweden 2, Switzerland 3; Subscribers: England 1, Finland 1, Netherlands 1, Norway 1; Members: England 2; Finland 1; France (St. Pierre & Miquelan Islands) 1, Iceland 1.

TABLE 2. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 112 (1998) by major field of study.

Subject	Articles	Notes	Total
Mammals	19*	14	31
Birds	14	10	24
Amphibians and reptiles	5	5	10
Fish	14	1	15
Invertebrates	6	2	8
Plants	13	8	21
Other	4**	0	4**
Totals	51	38	89

*Includes on article in News and Comment on historic wolf accounts.
**COSEWIC Subcommittee report for Fish and Marine Mammals: and Tributes to Dore and Raup; and Proposal for Endowed Chair in the Natural History of the Boreal Forest (History of the Taiga Field Station).

TABLE 3. Number of reviews and new titles published in Book Review section of *The Canadian Field-Naturalist* Volume 112 by topic.

	Reviews	New Titles
Zoology	30	132
Botany	14	23
Environment	20	55
Miscellaneous	4	13
Young Naturalists	–	64
Totals	68	287

Entomology: R. Anderson, Canadian Museum of Nature (2); Botany: Charles D. Bird, Erskine, Alberta (15), and Paul M. Catling, Agriculture Canada, Ottawa (8).

Additional reviewers — R. C. Anderson, University of Guelph, Ontario; C. Davison Ankney, University of Western Ontario, London; Robert H. Armstrong, Juneau, Alaska; Matt Austin, British Columbia Wildlife Branch, Victoria; Josh Avery, Texas Tech University, Lubbock; Robert C. Bailey, University of Western Ontario, London (2); W. M. R. Barclay, University of Calgary, Alberta; Jack F. Barr, Guelph, Ontario (2); David Barton, University of Waterloo, Ontario (1); M. C. Bateman, Canadian Wildlife Service, Saskville, New Brunswick; L. B. Best, Iowa State University, Ames; J. Roger Bider, Ecomuseum, Ste-Anne-de-Bellevue, Quebec; James P. Bogart, University of Guelph, Guelph, Ontario; Jeff Bowman, University of New Brunswick, Fredericton (1); Christopher J. Brand, National Wildlife Health Center, Madison, Wisconsin; Irwin Brodo, Canadian Museum of Nature, Ottawa, Ontario; Robert Butler, Canadian Wildlife Service, Delta, British Columbia; Lu Carbyn, Canadian Wildlife Service, Edmonton, Alberta; Tom J. Cade, The Peregrine Fund World Center for Birds of Prey, Boise, Idaho; Patrice M. Charlebois, Illinois Natrual History Survey, Lake Michigan Biological Station, Zion, Illinois; W. J. Cody, Agriculture and Agri-Food Canada, Ottawa (3); E. J. Crossman, Royal Ontario Museum, Toronto, Ontario (3); Don Cuddy, Ontario Ministry of Natural Resources, Kemptville; Steve Cumbaa, Canadian Museum of Nature, Otttawa; Chris Dau, U. S. Fish and Wildlife Service, Anchorage, Alaska; Ron Dermott, Great Lakes Lab for Fish and Aquatic Sciences, Canadian Centre for Inland Waters, Burlington, Ontario; Andrew Didiuk, SAMP/SHAP, Saskatoon, Saskatchewan; James J. Dinsmore, Iowa State University, Ames; George W. Douglas, Conservation Data Centre, British Columbia Ministry of Environment, Lands and Parks, Victoria; Raymond Duchesne, Universite du Quebec, Sainte-Foy; Jim Duncan, Balmoral, Manitoba; R. Yorke Edwards, Victoria, British Columbia; Herbert Fernando, University of Waterloo, Ontario (1); Jane A. Fitzgerald, Missouri Department of Conservation, Jefferson City, Missouri: Mike Fournier, Canadian Wildlife Service, Yellowknife, Northwest Territories; David Galbraith, Royal Botanical Gardens, Hamilton, Ontario; Anthony J. Gaston, Canadian Wildlife Service, Hull, Quebec; Lynn Gillespie, Canadian Museum of Nature, Ottawa, Ontario; John Gilhen, Nova Scotia Museum of Natural History, Halifax, Nova Scotia; Stev Gniadek, Glacier National Park, Montana; Paul Goosen, Canadian Wildlife Service, Edmonton, Alberta; Francois Goudreault, Ministre de l'Environment, Service de l'amenagement et l'exploitation de la faune, Hull, Quebec: Patrick T. Gregory, University of Victoria, Victoria, British Columbia (4); Wayne Grimm, Clayton, Ontario; Erich Haber, National Botanical Services, Ottawa,

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist* Volume 112 (1998) by issue.

	(1)	(2)	(3)	(4)	Total
Articles	157	138	123	119	537
Notes	9	21	31	21	82
Notices & Reports	3	7	7	5	22
Commentary & Tributes	0	16	8	16	40
Annual Meeting	0	0	9	0	9
Book Reviews*	21	14	13	18	66
Index				35	35
Advice to Contributors	0	0	1	1	2
Special Issue notice	0	0	0	1	1
Totals:	190	196	192	216	794

*Total pages for book review section include both reviews and new titles listings.

Ontario (3); David Hamer, Northern Lights College, Fort St. John, British Columbia; Paul Hamilton, Canadian Museum of Nature, Ottawa, Ontrio; Stuart Hay, Herbier Marie-Victorian Institut botanique, Université de Montreal, Montreal, Quebec; Stephen J. Hecnar, Lakehead University, Thunder Bay, Ontario; M. Brian Hickey, Raisin River Conservation Authority, Cornwall, Ontario (2); C. Stuart Houston, Saskatoon, Saskatchewan (2); J. Derek Johnson, Natural Resources Canada, Canadian Forest Service, Edmonton, Alberta; Mark K. Johnson, School of Forestry and Wildlife Management, Lousiana State University, Banton Rouge; M. R. Johnson, Wildlife Veterinary Resources, Gardiner, Montana; David J. Jude, University of Michigan, Ann Arbor; Jan Kamler, Texas Tech University, Lubbock; Brina Kessel, University of Alaska Museum, Fairbanks; P. G. Keven, University of Guelph, Ontario; Walt Klenner, Ministry of Forests, Kamloops, British Columbia (2); R. H. Kerbes, Canadian Wildlife Service, Saskatoon, Saskatchewan; Gordon L. Kirkland, Jr., Verebrate Museum, Shippenburg University, Pennsylvania; Stephen Laymon, Weldon, California; M. Ross Lein, University of Calgary, Calgary, Alberta; Nora Lewis, Winnipeg, Manitoba; Larry Licht, York University, North York, Ontario; Jon Lien, Memmorial University of Newfoundland, St. John's (2); David Langor, Northern Forestry Centre, Edmondon, Alberta; Harry G. Lumsden, Aurora, Ontario; Chris Mah, California Academy of Sciences, San Fracisco, California; André Martel, Canadian Musuem of Nature, Ottawa, and Bamfield Marine Station, British Columbia; John Maunder, Newfoundland Museum, St. John's, Newfoundland; Donald F. McAlpine, Natural Science Department, New Brunswick Museum, Saint John (4); W. Bruce McGillivray, Provincial Museum of Alberta, Edmonton; Martin K. McNicholl, Burnaby, British Columbia; L. David Mech, US Fish & Wildlife Service, North Central Forest Experiment Station, St. Paul, Minnesota (2); Francois Messier, University of Saskatchewan, Saskatoon (2); Antoine Morin, University of Ottawa, Ontario: A. Mosseler, Natural Resources Canada, Canadian Forest Service, Fredericton, New Brunswick; David Nagorsen, Royal British Columbia Museum, Victoria (2); Robert W. Nero, Manitoba Natural Resources, Winnipeg; Jim O'Hara, Agriculture and Agri-food Canada, Ottawa; Michael J. Oldham, Ontario Ministry of Natural Resources, Peterborough (5); John Ozoga, Munising, Michigan; Lawrence Powell, University of Calgary, Alberta (2); Gilbert Proulx, Alpha Wildlife Research and Management Limited, Sherwood Park, Alberta (4); Margo J. Pybus, Alberta Fish and Wildlife Division, Edmonton; Michael Raine, Golder Associates Ltd., Calgary, Alberta; T. E. Reimchen, University of Victoria, British Columbia; Claude Renaud, Canadian Museum of Nature, Ottawa; John Riley, Federaton of Ontario Natualists, Don Mills, Ontario; Raleigh J. Robertson, Queens University, Kingston, Ontario; Stewart B. Rood, University of Lethbridge, Alberta; Jean-Pierre Savard, Service canadien de la faune - Québec, Sainte-Foy; W. B. Scott, Kingston, Ontario; Fred Scott, Acadia University, Wolfville, Nova Scotia; F. W. Schueler, Oxford Station, Ontario (4); Spencer G. Sealy, University of Manitoba, Winnipeg; Diane Secoy [Smith], University of Regina, Saskatchewan; Kenton M. Stewart, State University of New York, Amherst; Kenneth W. Stewart, University of Manitoba, Winnipeg; David Stirling, Victoria, British Columbia; Vernon Thomas, University of Guelph, Ontario; Mark Wallace, Texas Tech University, Lubbock; Steve Wendt, Canadian Wildlife Service 351 St. Joseph's Blvd., Hull, Quebec; Michelle Wheatley, Sahtu Renewable Resources Board, Norman Wells and Talita, Northwest Territories (3); Heather Whitlaw, Lubbock, Texas (3); Dudley Williams, Scarborough College, University of Toronto: Jim Williams, St. Francis Xavier University, Antigonish, Nova Scotia.

I am also indebted to David Moore, President of the Ottawa Field-Naturalists' Club, the Club Council, Chairman Ron Bedford and the Publications Committee of the OFNC, for their support, to Alan German and Stephen Bridgett of the OFNC Computer Committee (in particular to Stephen for making several long trips out from the city to install a new modem and upgraded programming on the journal computer); to the Canadian Museum of Nature for continued access to its library and the facilities at the Natural Heritage Building, 1740 Pink Road, Aylmer, Quebec, and to Joyce for continuing encouragement at home.

FRANCIS R. COOK
Editor

The Committee On The Status Of Endangered Wildlife In Canada (COSEWIC): A 21-Year Retrospective

CHRISTOPHER C. SHANK

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Shank, Christopher C. 1999. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC): A 21-year retrospective. Canadian Field-Naturalist 113(2): 318–341.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) first designated risk status to Canadian species in 1978. This paper summarises the past 21 years of COSEWIC's existence by describing the past and current structure and function of the Committee, by analysing the list of species that have been designated status, and by highlighting currently outstanding issues. COSEWIC is comprised of representatives from governments, national conservation organizations, and technical experts but operates at "arm's length" from its member institutions. Designation of risk by COSEWIC carries no legal implications. COSEWIC maintains five non-quantitative "at-risk" categories (Extinct, Extirpated, Endangered, Threatened, Vulnerable). Two other categories (Not At Risk and Indeterminate) exist but do not appear on the list of *Canadian Species At Risk.* Designations are made at annual meetings based upon peer-reviewed status reports usually prepared under contract by independant experts. By 1998, COSEWIC had designated status to 447 species, subspecies and populations, 307 of which occur in the five at-risk categories. Analysis of the COSEWIC list of *Canadian Species At Risk* suggests that its composition is influenced by pragmatic matters such as existence of scientific knowledge, availability of knowledgeable authors, funding for report preparation, and differential public attitudes towards various taxa. Accordingly, the list's primary utility is at the level of the individual species rather than as a metric of biodiversity loss in Canada. Under proposed federal endangered species legislation, COSEWIC's role is expected to be assumed by a new entity. This "new COSEWIC" will be challenged in addressing several significant issues: treatment of species with ranges barely extending into Canada (peripherals), development of quantitative guidelines for at-risk categories, and the definition of nationally significant populations eligible for designation.

Key Words: Endangered Species, Threatened Species, Vulnerable Species, Species At Risk, Vulnerable Species, Indeterminate Species, status determination, Canada, COSEWIC, historical retrospective.

The Committee on the Status of Endangered Wildlife in Canada is the body having the mandate to designate species-at-risk in Canada. COSEWIC has been performing this role for 21 years and may soon be replaced by a structure and process arising out of proposed federal endangered species act. It therefore seems appropriate, at this time, to review and update Cook and Muir's (1984) chronicle of COSEWIC's early years. More specifically, the purpose of this paper is to provide a comprehensive description of how COSEWIC is currently structured and how it operates, to analyze the composition of the list of species designated by COSEWIC over the past 21 years, and to discuss some of COSEWIC's more challenging outstanding issues.

Origins of COSEWIC

As described more fully by Cook and Muir (1984), institution of COSEWIC was motivated by the appearance of numerous endangered species lists in Canada during the mid-1970s. These lists and designations, variously developed by organizations, governments, and individuals, were uncoordinated, contradictory, and not always credible. The perceived need was to develop a process leading to development of a single, scientifically sound, and nationally recognised list of species at risk in Canada. The motivation was therefore to provide information and recognition, not to provide the basis for actions mandated by endangered species legislation.

In May 1976, a national symposium on endangered species was organised by World Wildlife Fund Canada and the Canadian Nature Federation. Recommendation #2 was "That the Federal Provincial Wildlife Conference strike a standing committee consisting of representatives of the Federal and Provincial governments and appropriate conservation and scientific organizations for the purpose of establishing the status of endangered and threatened species and habitats in Canada" (page ix in Mosquin and Suchal 1977). The Federal Provincial Wildlife Conference, an annual gathering of Canadian Wildlife Directors, passed a resolution to this effect at their 40th meeting in July 1976 (Recommendation #6, page 177, Transactions of the

Editor's note: Christopher C. Shank is a past Chair of COSEWIC 1993–1996.

40th, Federal-Provincial Wildlife Conference, Fredericton, New Brunswick). Federal and provincial wildlife officials met in March 1977 and agreed to form a temporary committee. An inaugural meeting, attended by 12 jurisdictional/organizational representatives, was held in September 1977 at which time the name *Committee on the Status of Endangered Wildlife in Canada (COSEWIC)* was chosen (Cook and Muir 1984). Membership and procedures were finalised and species designations commenced at two meetings held in 1978. Meetings have been held annually ever since.

Institutional Structure and Procedures

Membership

The membership of COSEWIC is comprised of representatives from federal, provincial and territorial governments, national non-governmental environmental groups, Subcommittee Chairs drawn from the scientific community and a Chairperson who may simultaneously be a representative or a Subcommittee Chair (Table 1). Government members are at the Director level but have, in practice, usually been represented by senior-level biologists designated to represent their Director. The maximum number of voting members is 27.

Authority and Reporting Relationships

Central to COSEWIC's public credibility is its "arm's length" relationship with government and environmental organizations. Members, although most represent institutions, are expected to maintain strict impartiality and remain independent of non-scientific considerations. Members ensure that regional biological perspectives are considered but are expected to ignore political considerations. This has created tensions and put some members in a difficult relationship with their employers but the principle has been honoured, for the most part.

COSEWIC makes recommendations on procedures and designations to the annual meeting of the Canadian Wildlife Directors through an annual report submitted by the COSEWIC Chair. In keeping with COSEWIC's independence, the Directors have approved all designations and most procedural changes recommended by the Committee.

It should be noted that the membership of COSEWIC is broader in scope than the Canadian Wildlife Directors. Despite having representatives on COSEWIC, the federal Department of Fisheries and Oceans, the federal Department of Heritage (incorporating Parks Canada and the Canadian Museum of Nature) and the three non-governmental conserva-

TABLE 1. COSEWIC membership.

Member Type	Member
Provincial/Territorial Governments	Alberta British Columbia Manitoba New Brunswick Newfoundland/Labrador Nova Scotia Northwest Territories Ontario Quebec Prince Edward Island Saskatchewan Yukon
Federal Government	Canadian Wildlife Service (Department of Environment) Canadian Museum of Nature (Department of Heritage) Department of Fisheries and Oceans Parks Canada (Department of Heritage)
Non-Governmental Organizations	Canadian Nature Federation Canadian Wildlife Federation World Wildlife Fund Canada
Subcommittee Chairs	Amphibians and Reptiles Birds Fish and Marine Mammals Lepidopterans and Molluscs Vascular Plants, Mosses and Lichens Mammals Publicity
COSEWIC Chairperson	Membership At-Large or Non-member

tion organizations do not have a Director-level role in steering COSEWIC.

Mandate

COSEWIC's mandate is defined in the *COSEWIC Organization and Procedures Manual* comprised of policies, procedures, and definitions. Many of these items have been approved individually by the Directors but the entire document has never been finalised and approved as a single entity.

COSEWIC's overall mandate is to determine "...the national status of wild Canadian species, subspecies and separate populations suspected of being at risk."(http://www.cosewic.gc.ca/COSEWIC/Mandate.cfm). At the outset, this mandate was restricted to fish, birds, mammals, reptiles, amphibians, and plants. It was informally understood that only vascular plants were to be considered but in 1994 the scope was expanded to include two non-vascular groups (mosses and lichens) as well. In 1995, the Wildlife Directors approved treating lepidopterans and molluscs; the best studied and most endangered invertebrate groups representing a more manageable ~6000 species of the estimated ~44 000 known Canadian invertebrate species (Appendix 1 of Mosquin et. al. 1995: Appendix 1).

COSEWIC designations refer strictly to Canadian populations. In the case of non-endemic species, status in the United States or at the global scale is not considered in the designation process except as background information. This has broader implications in the case of so-called "peripheral species" as discussed below. A loose understanding has been that marine species will be treated within the 200 mile marine territorial zone. Recent invaders are considered to have occurred in Canada within the past 50 years and are excluded from deliberations unless they are "...natural invaders and, in the opinion of the Committee, have produced viable populations in Canada" (COSEWIC Organization and Procedures Manual 1992). International migrants are considered to be Canadian species if a critical portion of their life cycle (e.g., breeding) occurs in Canada.

RENEW

In 1988, the Wildlife Directors created a program called Recovery of Nationally Endangered Wildlife (RENEW) which oversees institution of recovery teams and development of recovery plans for terrestrial vertebrates listed as Extirpated, Endangered, or Threatened (Campbell 1990). RENEW's mandate has been officially restricted to terrestrial vertebrates because this is the only group over which the Wildlife Directors exercise clear authority.

The roles of COSEWIC and RENEW are distinct and complementary. COSEWIC determines species status on a scientific basis with no reference to social, fiscal, or political considerations. RENEW, on the other hand, oversees recovery planning which balances species recovery priorities with a host of competing "real world" concerns. By 1997, RENEW had approved 39 recovery teams and recovery plans for 17 species for the 46 terrestrial vertebrates then listed as Extirpated, Endangered, or Threatened. Some teams treat more than one listed species and some species have been delisted and the recovery team disbanded.

Legal Significance of COSEWIC Designations

Declaration of species at-risk status carries no legal consequences. The COSEWIC list of *Canadian Species At Risk* appears as a public document but is not encompassed in legislation. At irregular intervals, designations have been published in the Canada Gazette. COSEWIC designations are intended solely to draw official and public attention to the possible loss of Canadian species with the expectation that jurisdictions will utilise their mandates to halt species declines and ensure recovery. The RENEW process is the only automatic, institutional response to a COSEWIC designation and is limited to Extirpated, Endangered, and Threatened terrestrial vertebrates; species listed as Vulnerable are not treated by RENEW.

Voting

COSEWIC meetings are held once every year at which time policies, procedures, and species designations are debated and approved. Lengthy discussions often take place aimed at developing a consensus amongst members as to the appropriate designation to be accorded the species. If a vote becomes necessary, a two-thirds majority of members present is required for passage. No jurisdiction has veto power over status assignments for species under its authority although COSEWIC commonly accepts reasonable requests by range jurisdictions for deferral of status reports.

Status Reports

COSEWIC's scientific credibility is based upon its use of documentation that accurately and completely summarises all available information on the current status the species in Canada. The Subcommittee Chairs have responsibility for preparation of status reports within their taxonomic realm of expertise. The Subcommittee Chairs develop a priority list of species to be considered, contract knowledgeable authors, shepherd the report through to completion, and coordinate peer review within a panel of experts comprising the body of the Subcommittee. Status reports are developed based on the best scientific information available; background research is not generally supported. Completed status reports are submitted to range jurisdictions at least six months prior to the annual meeting to allow for local input and legally-required consultation with aboriginal groups. The COSEWIC general membership receives status reports at least two months prior to the annual meeting. Status reports become public documents upon approval of the report and species designation by the full Committee at the annual meeting. The Subcommittee Chairs commission update reports when a species' status is suspected to have changed or at 10-year intervals.

Secretariat and Standing Committee

A Secretariat, funded by and housed within the federal Canadian Wildlife Service (CWS), organises the annual general meeting, handles archives and documentation and is the public contact point for COSEWIC. An *ad hoc* Standing Committee, comprised of the COSEWIC Chair, Subcommittee Chairs, and Secretariat members, deals with matters arising between annual meetings.

Financing

The Canadian Wildlife Service presently funds all Secretariat activities and member organizations support participation by their representatives. The work of the Subcommittee Chairs is usually supported by their institutions, however, with the increasing workloads and funding cutbacks, an increasing amount of Subcommittee work is currently being done on a volunteer basis.

COSEWIC itself has no dedicated budget for status report preparation. Individual organizations may commission status reports in-house, or commission status reports directly. On occasion, status reports may be donated to COSEWIC free of charge. Currently, contracted status reports cost an average of about $3500, although several have cost as much as $10 000. The cost of preparing a status report depends upon the amount of information that is available, and the time required for collecting and analysing it. Generally, funds are not provided to gather new information but, in some cases, such as for molluscs and plants, authors must do field checks to determine whether a reported population is still extant. It is recognised that most report authors have not been compensated at a level commensurate with their efforts and specialised knowledge.

Over the years, various institutions (notably the Canadian Wildlife Service, World Wildlife Fund Canada, the Canadian Wildlife Federation, the Department of Fisheries and Oceans) have contributed significant amounts of funding for status reports (Cook and Muir 1984; Campbell 1989, 1991, 1992, 1993, 1996, 1997). In the late 1980s and early 1990s (ending in 1995), there was a matching funding arrangement in place which provided about $40 000 per year for preparation of status reports. World Wildlife Fund Canada and later the Canadian Wildlife Federation provided matching funding for contributions provided by government members of COSEWIC. This funding was split between the various subcommittees and the species funded were chosen based on recommendations from the subcommittee chairs. Recently, the Canadian Wildlife Service has been the major contributor towards preparation of status reports, and has approximately tripled the amount of funding available, largely in response to a current need for update reports. Some member organizations continue to contribute to status reports on species of interest to them.

Definitions

Species

COSEWIC defines "species" as "any indigenous species, subspecies, variety or geographically defined population of wild fauna or flora" (Campbell 1996). The terminology is confusing because the definition uses the term "species" to refer not only to the taxonomic species but also their constituent parts—subspecies and populations. No fully satisfactory term has been found to collectively refer to species, subspecies, and populations. In this paper, I will use the unmodified term "species" in the COSEWIC sense and refer to "taxonomic" species when the term is used in the traditional, biological connotation.

At-Risk Categories

COSEWIC designates taxonomic species, subspecies, and populations into five at-risk categories; Extinct, Extirpated, Endangered, Threatened, and Vulnerable. Current definitions are presented by Campbell (1996). Together, the designations within the five at-risk categories comprise the list of *Canadian Species At Risk*

Over the past 21 years, status definitions have changed to better reflect the intent of the category and a better understanding of the biology of extinction. For earlier definitions, see Cook and Muir (1984) and Campbell (1989, 1996). The only category in which the fundamental concept behind the category changed has been for the Vulnerable category. The original category was termed "Rare" in the recognition that some degree of risk is conferred by numerical rarity or restricted spatial distribution. In 1988, the category name was changed to "Vulnerable" (Campbell 1990). The definition was subsequently changed to place emphasis upon life history characteristics or particular circumstances that place a species at potential risk, rather than simply on rarity or distribution. Following review by the Subcommittees, all Rare designations were changed to Vulnerable in 1990.

The definitions of COSEWIC risk categories are non-quantitative leading to concerns about whether assignment of risk status has been consistent and justifiable. The Committee is currently considering quantitative designation guidelines modelled on the IUCN Red List criteria (Baillie and Groombridge 1996).

Other Categories

Taxonomic species, subspecies, and populations are also designated into the two other categories; Not-at-Risk and Indeterminate (Campbell 1996).

Because of a reluctance to state that a species is definitively not at risk, a paradoxical category "Not

In Any Category" (NIAC) was originally used to indicate that the status of the species did not warrant designation in any at-risk category. In 1990, this was changed to "Reports Accepted – No Status Designation Required" (RANSDR) (Campbell 1991). In 1994, COSEWIC adopted a more straightforward approach by designating such species as "Not At Risk" (Campbell 1996). All species were transferred from NIAC to RANSDR to Not At Risk. There are several reasons for developing status reports for species found to be Not At Risk. These include initial uncertainty as to status, submission of status reports not commissioned by the Subcommittee Chairs, response to requirements for status assessment arising from international agreements such as the Convention on the Trade in Endangered Species (CITES), and the need for baseline documentation of status against which future status can be assessed.

COSEWIC's *Organization and Procedures Manual* states that the Committee will determine status on the basis of the best available scientific information; i.e., designation should not be delayed until all data the Committee would like to have becomes available. However, experience has shown that there are sometimes critical data gaps that make it impossible for COSEWIC to reach a decision. Such species are designated as "Indeterminate". Prior to 1994, this category was burdened with the awkward name "Insufficient Scientific Information on which to Base a Designation".

Analysis of Designations

The 1998 List of Species At Risk

Currently, the COSEWIC list of *Canadian Species At Risk* stands at 307* taxonomic species, subspecies and populations in the five at-risk categories (Table 2). A further 121 taxonomic species, subspecies and populations have been determined to be Not At Risk and 19 to be Indeterminate. In total, COSEWIC has made determinations on 447 taxonomic species, subspecies, and populations. A list of species designated through 1998, together with their designation history and province of occurrence, is given in Appendix 1. This list differs slightly from the current list of *Canadian Species At Risk* (COSEWIC 1998) in a few spellings and in clarifying of population/subspecies identity.

Growth of The COSEWIC List

On average, the list of Species At Risk has grown at a rate of 14.5±6.5 (S.D.) species per year with the range of new species designations being from 4 to 26 (Table 3). Determining number of species at risk must take into account previously designated species that were split into two or more infra-specific designations and those that were downlisted to Not At Risk. On average, just under 6 species per year are listed as Not At Risk with the range being 0 to 15. There were no species designated as Indeterminate until 1990.

Proportion of Designations by Taxonomic Group

Table 2 shows the proportion of designations by taxonomic group used by COSEWIC. Currently, 62% of designations are vertebrates, 36% plants/lichens/mosses, and 2% invertebrates. By contrast, larger proportions of plants and invertebrates and smaller proportions of vertebrates are listed under the US Endangered Species Act [28% vertebrates, 59% plants, 14% for invertebrates (U.S. Fish and Wildlife website http://www.fws.gov/r9endspp/boxbtl.html, dated 20 April 1998)].

The proportion of COSEWIC designations falling within different taxonomic groups has evolved over the years of the Committee's operation (Figure 1). In the early years, COSEWIC listed primarily taxonomic species of charismatic birds and mammals. Over time, the proportion of bird and mammal designations has declined while those for fish and plants increased.

Proportion of Designations in Risk Categories

In total, almost half of the at-risk designations are in the Vulnerable category with just under a quarter in both of the Endangered and Threatened categories (Table 2). About 7% of all designations are in the Extinct and Extirpated categories combined.

There are differences between taxonomic groups in the distribution of designations across the five at-risk categories (Table 2). Fish and amphibians are characterised by more Vulnerable designations than the between-group average whereas plants have been designated Vulnerable less frequently (Table 2). A greater proportion of plants falls into the Threatened category relative to the average of all groups. There are few fish designated as Endangered relative to the cross-taxa average and, by contrast, relatively more birds designated as Endangered.

These differences reflect priority in status report preparation as well as to differences in susceptibility to extinction. For example, the percentage of Vulnerable designations for mammals has increased with the growing number of designations (Figure 2). In 1978, there were seven mammal designations of which only one (14%) was Vulnerable. In 1998, there are 51 mammal designations of which 49% are Vulnerable. In general, species more seriously at risk in high-profile groups such as birds and mammals were designated early in the COSEWIC process. Continued allocation of funds to status report preparation in these well-known groups has led to a tendency towards an increasing proportion of lower risk designations.

*In fact, the number is properly 306. The two populations of Bowhead Whale listed as Endangered comprise the extant Canadian population and should be combined.

TABLE 2. A summary of the 1998 COSEWIC list of species-at-risk in Canada showing the number of designations of each risk category within each taxonomic group. Parenthetical values are the percentage of the taxon designated at various levels of risk.

Category	Birds	Mammals	Amphibians	Reptiles	Fish	Inverts	Plants	Mosses	Lichens	Total
Extinct	3(6)	2(4)	0(0)	0(0)	4(6)	1(17)	0(0)	0(0)	0(0)	10(3)
Extirpated	2(9)	4(8)	0(0)	1(7)	2(3)	1(17)	2(2)	0(0)	0(0)	12(4)
Endangered	17(35)	12(23)	2(36)	3(20)	4(6)	2(33)	32(30)	0(0)	1(25)	72(23)
Threatened	6(12)	9(17)	0(0)	4(27)	15(23)	1(17)	36(34)	1(100)	0(0)	72(23)
Vulnerable	21(43)	25(48)	7(64)	7(47)	41(62)	1(17)	35(33)	0(0)	3(75)	140(46)
Total	49	52	9	15	66	6	105	1	4	307
% All Designations	16	17	3	5	21	2	34	0	1	

Proportion of The Canadian Biota Designated At Risk

Approximately 71 000 species (exclusive of viruses) are known to exist in Canada (Mosquin et. al. 1995: Appendix 1). The 233 taxonomic species designated risk status by COSEWIC represents only 1.7% of the ~14 000 known Canadian species within COSEWIC's mandate while the 352 taxonomic species examined to date represent less than 2.5% of this total. Only four taxonomic species (plus two subspecies) of the ~44 000 Canadian invertebrate species have been listed because COSEWIC has only recently begun to examine a small range of invertebrate species (i.e., the 6129 species of lepidopterans and molluscs). The percentage of Species At Risk in the better known taxonomic groups is much higher, ranging from 14.3% in reptiles and amphibians to 2.9% in vascular plants (Table 4).

Update Reports

In 77 cases, COSEWIC has considered update reports for previously designated species (Figure 3). Five original designations were split into 12 subspecies or population designations. In nine cases, species were removed from the list of Species At Risk (i.e., assigning a status of Not At Risk). In 41 cases, the original designations were confirmed, 17 were down-graded

TABLE 3. Growth of the COSEWIC list; 1978–1998. Total designations take into account new listings and previously existing listings that were split, uplisted from Not-At–Risk (NAR) or Indeterminate (I) and delisted to NAR or I.

Year	New at-Risk designations	Splits	Delist To NAR or I	Uplist from NAR or I	Total At-risk designations	NAR	I	Total
1978	17				17	4	0	21
1979	7				24	8	0	32
1980	8				32	9	0	41
1981	6				38	9	0	47
1982	4				42	10	0	52
1983	12				54	10	0	54
1984	21				75	15	0	80
1985	23				98	17	0	115
1986	18			1	116	22	0	138
1987	24		1		140	30	0	170
1988	26				166	34	0	200
1989	17	1			182	49	0	231
1990	12				194	56	2	252
1991	19	1		2	214	61	4	279
1992	16	1			230	67	5	302
1993	8		1		237	79	9	325
1994	19				256	86	10	352
1995	8				264	92	11	367
1996	17		5		276	106	13	395
1997	15				291	113	19	423
1998	19		3	1	307	121	19	447

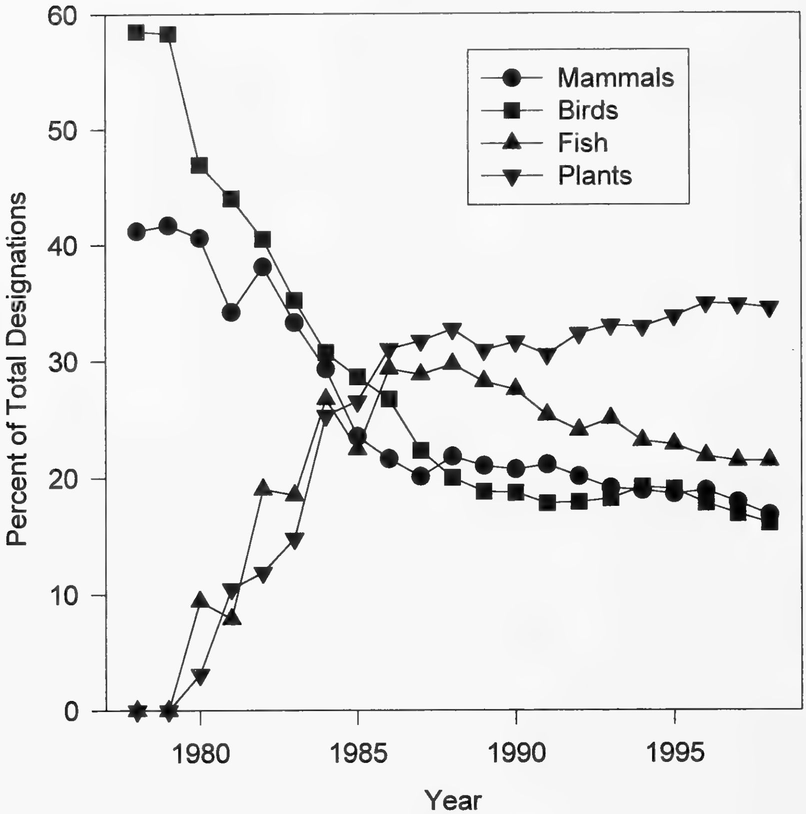

FIGURE 1. Proportion of total at-risk designations within each of the major taxonomic groups. Data for reptiles, amphibians, invertebrates, and lichens are not included because they comprise a small proportion of total listings.

to a lower category of risk, and, in 19 cases, species were uplisted to a higher category of risk.

Proportion of Infra-Specific Designations

COSEWIC designations include subspecies and populations as well as full, taxonomic species. Of the 307 at-risk designations, 233 (76%) are taxonomic species (Table 4). The remaining 71 (23%) are populations or subspecies (or varieties) of taxonomic species that are not at risk in Canada.

The percentage of infra-specific designations varies dramatically between taxonomic groups (Table 4). For example, 44% of mammal designations and 1% of plant designations are at the population level as compared to 10% for all designations. Over 53% of reptile designations are the subspecific level as compared to a cross-taxa average of 14%. A total of 91% of fish designations and 89% of plant listings are at the taxonomic species level compared to only 40% of reptile designations.

These trends largely reflect the number of species in a taxonomic group and/or the scientific and popular attention they receive. For example, there are few (194) mammal species in Canada and designation of the well-known, taxonomic species were largely completed early in COSEWIC's operations leaving the Mammal Subcommittee with the opportunity to place greater emphasis on populations and subspecies in later years (Figure 2). The percentage of subspecies and population designations for mammals increased from 30% in 1980 (10 mammal designations) to 56% in 1998 (52 mammal designations). By contrast, work is only partially completed on the 3123 species of Canadian vascular plants (Mosquin et al. 1995: Appendix 1) necessitating that emphasis be retained at the taxonomic species level.

Wilcove et al. 1993 noted that the "overwhelming majority" of recent mammal and bird listings under U.S. Endangered Species Act have been at the subspecies or population level. This might lead to the impression that the majority of listings in the U.S. are subspecies and populations. However, populations of invertebrates and plants, which comprise 77% (Wilcove et al. 1993: Table 1) of US designations in the period 1985-1991, can only legally be listed at the

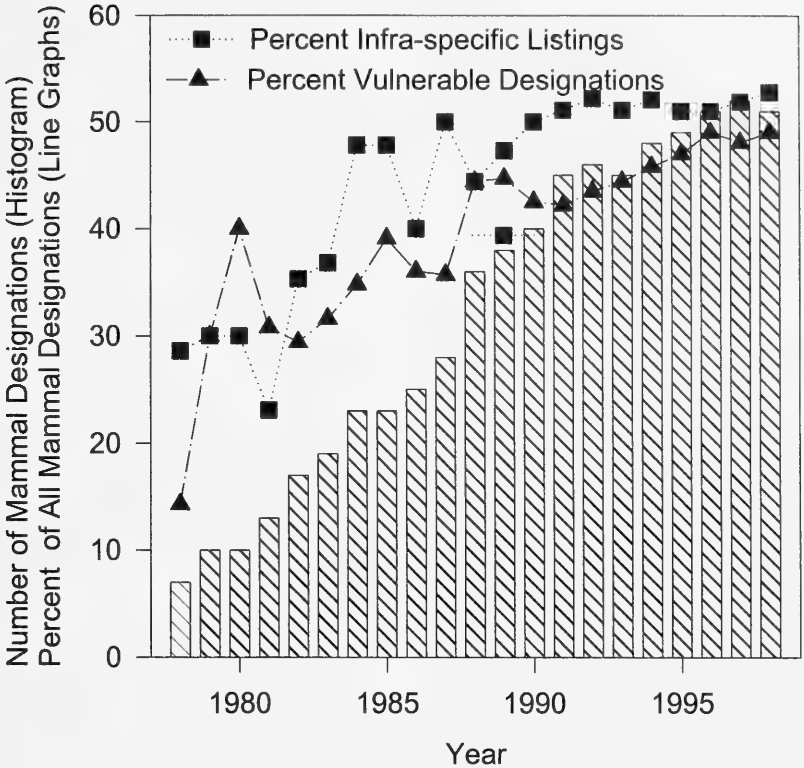

FIGURE 2. The cumulative number of mammals designated at-risk is depicted by the histogram. The line graphs indicate the percentage of mammals designated at the subspecies or population level and the percentage of mammals listed as Vulnerable. As the number of mammal designations increased through time, the percentage of subspecies, populations and Vulnerable designations also increased.

taxonomic species level under the Endangered Species Act with the result that only 20% of all listings between 1985-1991 were below the species level.

COSEWIC has designated a greater percentage of populations than has the U.S. (10% vs. 2%) and somewhat fewer subspecies (14% vs. 18%). However, the total percentage of designations below the species level is only slightly higher in Canada (24% in Canada vs. 20% in the US) (Table 4 and Wilcove et al. 1993). In Canada 56% of mammal designations are populations or subspecies versus 70% in the US. In the US, 80% of bird listings are below the species level as compared to 26% in Canada. It is not clear to what degree these differences might be attributable to dissimilarities in the designation processes of Canada and the U.S. or to underlying differences in the national faunas.

Geographic Distribution of Species At Risk

At-risk designations are unevenly distributed across the provinces and territories (Table 5). Ontario has by far the most designations (129) followed by British Columbia (77) and Quebec (56). The correlation between the number of at-risk designations is significantly correlated to provincial/territorial human population numbers ($r = 0.93$, $p = <0.001$) but not with provincial population density ($r = 0.09$, $p = 0.77$). The dissociation between provincial population numbers and density reflects the concentration of the Canadian population along the U.S.-Canada border with approximately three-quarters of Canada's ~29 million people living in a narrow strip along the border. Coincident with this population concentration are the extensions of several widespread ecosystems that barely extend into Canada (see peripheral species, below). A contributing factor may also be the differential willingness of provinces to support species-at-risk research and status report preparation.

COSEWIC's Problematic Issues

Peripheral Species

COSEWIC's mandate is to consider the status of species in Canada. Accordingly, the situation of a species outside Canada is considered as general background information but does not influence the

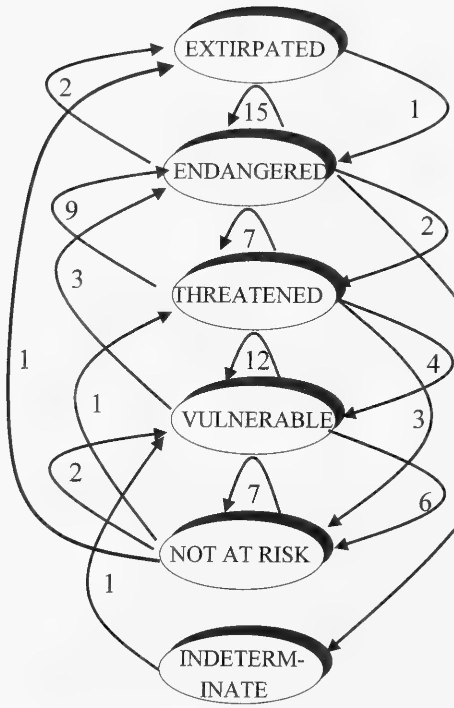

FIGURE 3. Re-examination of 77 previous designations based upon updated status reports. The arrows indicate confirmation or reassignment of status. The integers indicate the number of redesignations or confirmations.

determination of status in Canada. A species whose northern distribution barely extends into Canada, a "peripheral species", is assessed solely on status in Canada regardless of whether the species is at-risk or secure in the United States. The international border transects the northern tip of several major ecosystems, most notably the Carolinian Forest of southwestern Ontario, the shortgrass prairie of southwestern Saskatchewan /southeastern Alberta, and the xeric Okanagan of south-central British Columbia. Canada's list of species at risk is heavily weighted to peripheral species confined to these three ecosystems. COSEWIC has been unable to objectively determine which of the previously listed species might be considered as peripherals, but the best estimates of the Subcommittee Chairs are that about 40% of birds and 33% of terrestrial mammal designations might be considered peripheral species (R. James [R.R. #3, Sunderland, Ontario L0C 1H0] and D. Nagorsen [Royal British Columbia Museum, 675 Belleville Street, Victoria, British Columbia V8W 9W2], personal communication 1996).

Designations of peripheral species demonstrably secure in the U.S. might be criticised as being biologically trivial, as conveying the public impression of a deeper endangered species crisis than actually exists, and in diverting attention and resources from the recovery of higher priority species. However, COSEWIC has considered designation of peripheral species as consistent with its mandate of providing objective, science-based assessment of species occurring *in Canada* and that it is the role of RENEW and management agencies to undertake the appropriate recovery action. The recovery plan may recommend that no action be taken but at least the designation ensures that this decision is based on reasoned choice rather than simple neglect.

Subspecies

Traditionally, subspecies (or races and varieties) are commonly differentiated on the basis of morphometric measures with overlapping statistical distributions and subjective criteria such as colour. The recent development of molecular techniques rarely clarifies subspecies identity. Consequently, subspecific taxonomy is often controversial and individuals are often not assignable unequivocally to a particular subspecies. Therefore, COSEWIC has annotated its subspecies designations with a geographic description thereby describing an unmistakable collectivity defined by a line on a map. This has sometimes resulted in confusion as to whether a population or the subspecies has been designated.

Populations

COSEWIC's mandate includes responsibility to designate risk status to populations that are of national significance. The Committee has struggled with establishing procedures for determining which of a species' potentially numerous populations are of national significance and therefore eligible for designation. The challenge is to establish consistent rules for delineating populations and for establishing whether they are nationally significant. To date, COSEWIC has not adopted a set of rules that satisfactorily encompass the broad diversity of natural situations arising while continuing to make biological and intuitive sense. Consequently, the set of populations COSEWIC has designated has therefore been *ad hoc* and inconsistent. COSEWIC has been considering an ecological approach to establishing national significance of populations. Nonmarine environments have been divided into eight "National Ecological Areas" (Figure 4) each of which has the capability of harbouring a "nationally significant population". The concept is based on the presumed significance of behavioural and genetic adaptations to regional conditions. In practice, the ecological approach to population significance has been problematic because of difficulties in forcing complex and dynamic population structures into consistent "pigeon-holes".

TABLE 4. Number and percentage of at-risk designations occurring at the taxonomic species, subspecies, and population level. The last two lines indicate the number of species occurring in Canada and the percentage of Canadian species that have been designated at-risk.
The number of taxonomic species in Canada within COSEWIC's mandate is calculated from Appendix 1A in Mosquin et al. (1995). The approximate number of described Canadian species is 71 000 exclusive of viruses (Mosquin et al. 1995) indicating that COSEWIC's mandate deals with 20% of known Canadian species.

Category	Bird	Mammal	Fish	Amphibia	Reptile	Invert	Plant	Moss	Lichen	Total
Taxonomic Species	36(74)	23(44)	60(91)	6(67)	6(40)	4(67)	93(89)	1(100)	4(100)	233(76)
Subspecies	11(22)	6(12)	3(5)	1(11)	8(53)	2(33)	11(10)	0	0	42(14)
Population	2(4)	23(44)	3(5)	2(22)	1(7)	0	1(1)	0	0	32(10)
Total	49	52	66	9	15	6	105	1	4	307
Canadian Taxonomic Species	426	194	1091	42†	42†	6129*	3123**	997***	~2000	14044
% Canadian Taxonomic Species-At-Risk	8.5	11.9	5.5	14.3	14.3	<0.1	2.9	<0.1	<0.1	1.7

Parenthetical values are percentages.
*Restricted to Mollusca and Lepidoptera
**Restricted to vascular plants (Equisetophyta, Pterophyta, Pinophyta, Magnoliophyta).
***Bryophyta and Lycopodiophyta
†**Editor's Note:** Because of new discoveries, spliting former species, and elevation of some subspecies to species level the revised totals for amphibian is 46 and for reptiles is 44 or 45 by 1998. The Mosquin et al. totals are retained here for consistency in comparison.

What Does the COSEWIC List Tell Us About a Canadian Endangered Species Crisis?

The continuing growth of the COSEWIC list might be interpreted as demonstration of a currently deepening endangered species crisis. But, whereas COSEWIC designations provide a great deal of information about the plight of individual species, some of whose situation is worsening, the list of Canadian Species-At-Risk itself actually provides little insight into the changing status of the entire national biota.

Over 20 years, COSEWIC has examined 447 species, subspecies and population of the ~71 000 known Canadian species (exclusive of viruses) (Mosquin et al. 1995: Appendix 1) and the ~14 000 within its mandate (calculated from Mosquin et al. 1995:Appendix 1). Consequently, the COSEWIC list of Species At Risk reflects the process of catching up with a long legacy of species endangerment more than of monitoring a current process. For example, the median date of disappearance of the 23 species listed as Extinct or Extirpated is about 1928 (range <1800–1991, most dates are estimated). Two subspecies and one taxonomic species are considered to have disappeared from Canada within the lifetime of COSEWIC (Banff Longnose Dace in 1986, the Greater Prairie Chicken in 1987, and the Karner Blue Butterfly in 1991).

The extent to which the COSEWIC list is dominated by the process of designation can be seen in

TABLE 5. Number of At-Risk designations (full species, subspecies, populations) in each province and territory. X = Extinct, XT = Extirpated, E = Endangered, T = Threatened, V = Vulnerable. The table does not include marine species.

Province/Territory	X	XT	E	T	V	AT-RISK Designations
Alberta	1	3	10	7	17	38
British Columbia	1	2	16	19	39	77
Manitoba	1	3	6	5	23	38
New Brunswick	4	0	5	2	10	21
Newfoundland/Labrador	4	0	6	1	8	19
Northwest Territories	0	0	7	4	11	22
Nova Scotia	4	0	7	6	9	26
Ontario	4	6	29	31	59	129
Prince Edward Island	1	0	1	0	3	5
Quebec	4	0	7	15	30	56
Saskatchewan	1	3	9	7	17	37
Yukon	0	0	1	1	6	8

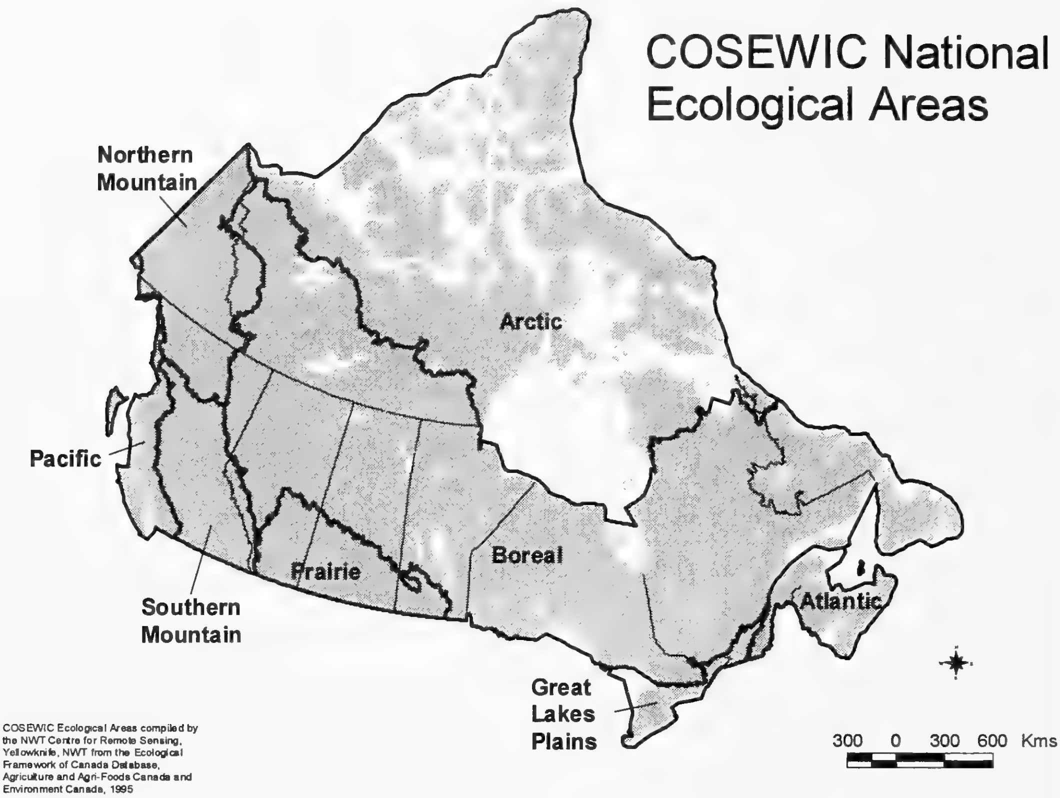

FIGURE 4. National Ecological Areas of Canada used by COSEWIC as a guideline for establishing the national significance of terrestrial and freshwater populations.

the way in which the proportion of designations has changed over the past 20 years with respect taxonomic groups (Figure 1) and infra-specific designations (Figure 2).

Better insight into the current state of species at risk is provided by the update reports (Figure 3). In the 77 cases that species status was re-examined, 25% were considered to have worsened, 22% to have improved, and 53% to have remained the same. This provides little support for the supposition that Canada is facing a growing endangered species crisis.

The Future of COSEWIC

Over the past several years, the Canadian government, in consultation with stakeholders and provincial/territorial governments, has been formulating a federal endangered species act. The legislation will replace COSEWIC with a new body charged with responsibility to provide objective, scientific assessments of Canadian species-at-risk. At the time of this writing, the composition, function, and reporting relationships of this new body have not been made public.

Conclusions

COSEWIC has proven to be an effective instrument in providing credible assessment of status for Canadian species. Status assessment has provided recognition of individual species' plights by scientists and the public and has provided the scientific basis for subsequent recovery actions. However, only a small fraction of the country's biota has been assessed and the composition of the list is influenced by the number of species in a taxonomic group and the state of available scientific knowledge. Consequently, growth of the COSEWIC list of *Canadian Species at Risk* should not be considered as collective indicator of a decline in Canadian biodiversity.

Significant challenges for COSEWIC and/or its successor will be to establish more quantitative status definitions, to adopt definitions and procedures to deal with peripheral species and to develop scientifically credible criteria for designating nationally significant populations, and to secure enhanced and secure funding for the administration and preparation of status reports.

Acknowledgments

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COSEWIC is a process that has engendered considerable devotion in participants. This has been particularly true of the Subcommittee Chairs and the status report authors whose time and energies, often undertaken with little or no compensation, have been fundamentally responsible in making COSEWIC a success.

Literature Cited

Baillie, J., and **B. Groombridge.** 1996. The IUCN Species Survival Commission 1996 IUCN Red List of Threatened Animals. IUCN, Gland.

Campbell, R. R. 1989. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: V. Canadian Field-Naturalist 103(2): 147–157.

Campbell, R. R. 1990. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: VI. Canadian Field-Naturalist 104(1): 1–6.

Campbell, R. R. 1992. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: VIII. Canadian Field-Naturalist 106(1): 1–6.

Campbell, R. R. 1993. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: IX. Canadian Field-Naturalist 107(4): 395–401.

Campbell, R. R. 1996. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: X. Canadian Field-Naturalist 110(3): 454–461.

Campbell, R. R. 1997. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: XI. Canadian Field-Naturalist 111(2): 249–257.

Cook, F. R., and **D. Muir.** 1984. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC): history and progress. Canadian Field-Naturalist 98(1): 63–70.

COSEWIC. 1998. Canadian species at risk: April 1998. COSEWIC Secretariat, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario.

Mosquin, T., and **C. Suchal.** *Editors.* 1977. Canada's threatened species and habitats. Canadian Nature Federation Special Publication Number 6. 186 pages.

Mosquin, T., P. G. Whiting, and **D. E McAllister.** 1995. Canada's biodiversity: the variety of life, its status, economic benefits, conservation costs and unmet needs. Canadian Museum of Nature, Ottawa.

Wilcove, D. S., M. McMillan, and **K. C. Winston**. 1993. What exactly is an endangered species? An analysis of the U.S. Endangered Species List: 1985–1991. Conservation Biology 7(1): 87–93.

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APPENDIX 1. The 1998 COSEWIC List of Species-At-Risk, Not-At-Risk, and Indeterminate.

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
				EXTINCT (X)		
MAMMALS						
Sea Mink	*Mustela*	*macrodon*			1986	NB,NF
Woodland Caribou (Dawson's)	*Rangifer*	*tarandus*	*dawsoni*		1984	BC
BIRDS						
Great Auk	*Pinguinus*	*impennis*			1985	NF,NB,NS,QC
Labrador Duck	*Camptorhynchus*	*labradorius*			1985	NF,NB,NS,QC
Passenger Pigeon	*Ectopistes*	*migratorius*			1985	MB,NB,NS,ON,PE,QC,SK
FISH						
Banff Langnose Dace	*Rhinichthys*	*cataractae*	*smithi*		1987	AB
Blue Walleye	*Stizostedion*	*vitreum*	*glaucum*		1985	ON
Deepwater Cisco	*Coregonus*	*johannae*			1988	ON
Longjaw Cisco	*Coregonus*	*alpenae*			1985	ON
INVERTEBRATES						
Eelgrass Limpet	*Lottia*	*alveus*			1996	NF,NS,QC
				EXTIRPATED (XT)		
MAMMALS						
Black-footed Ferret	*Mustela*	*nigripes*			1978	AB,MB,SK
Gray Whale	*Eschrichtius*	*robustus*		Atlantic	1987	
Grizzly Bear	*Ursus*	*arctos*		Prairie	NIAC 1979; split and listed XT 1991	AB,MB,SK
Atlantic Walrus	*Odobenus*	*rosmarus*		NW Atlantic	1987	
BIRDS						
Greater Prairie Chicken	*Tympanuchus*	*cupido*			E 1978; uplisted to XT 1990	AB,MB,ON,SK
Sage Grouse	*Centrocercus*	*urophasianus*	*phaios*		1997	BC
REPTILES						
Pygmy Short-horned Lizard	*Phrynosoma*	*douglasi*			1992	BC
FISH						
Gravel Chub	*Erimystax*	*x-punctatus*			E 1985; uplisted to XT 1987	ON
Paddlefish	*Polydon*	*spathula*			1987	ON
INVERTEBRATES						
Karner Blue Butterfly	*Lycaeides*	*melissa*	*samuelis*		1997	ON
PLANTS						
Blue-eyed Mary	*Collinsia*	*verna*			1987	ON
Illinois Tick Trefoil	*Desmodium*	*illinoense*			1991	ON
				ENDANGERED (E)		
MAMMALS						
Bowhead Whale	*Balaena*	*mysticetus*		E Arctic	1980	
Bowhead Whale	*Balaena*	*mysticetus*		W Arctic	E in 1980; confirmed 1986	
Newfoundland Pine Marten	*Martes*	*americana*		Newfoundland	NAR 1979; T 1986; E 1996	NF
Peary Caribou	*Rangifer*	*tarandus*	*pearyi*	High Arctic	T 1979; split and designated E; 1991	NT
Peary Caribou	*Rangifer*	*tarandus*	*pearyi*	Banks Island	T 1979; split and designated E; 1991	NT
Right Whale	*Eubalaena*	*glacialis*			E 1980; confirmed 1985, 1990	
Swift Fox	*Vulpes*	*velox*			XT 1978; E 1998	AB,SK

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Vancouver Island Marmot	*Marmota*	*vancouverensis*			E 1978; confirmed 1997	BC
White Whale (Beluga)	*Delphinapterus*	*leucas*		SE Baffin-Cumberland Snd.	E 1990	NT
White Whale (Beluga)	*Delphinapterus*	*leucas*		St. Lawrence	E 1983; confirmed 1997	QC
White Whale (Beluga)	*Delphinapterus*	*leucas*		Ungava Bay	1988	NT
Wolverine	*Gulo*	*gulo*		Eastern	RARE 1982; split and designated E; 1989	QC,NF
BIRDS						
Acadian Flycather	*Empidonax*	*virescens*			1994	ON
Burrowing Owl	*Speotyto*	*cunicularia*			T 1979, 1991; uplisted to E 1995	AB,BC,MB,SK
Eskimo Curlew	*Numenius*	*borealis*			1978	NT
Harlequin Duck	*Histrionicus*	*histrionicus*		Eastern	1990	QC,NF,NB,NS
Henslow's Sparrow	*Ammodramus*	*henslowii*			T 1984; uplisted to E 1993	ON
King Rail	*Rallus*	*elegans*			V 1985; uplisted to E 1994	ON
Kirtland's Warbler	*Dendroica*	*kirtlandii*				ON,QC
Loggerhead Shrike	*Lanius*	*ludovicianus*	*migrans*		T 1986; split 1991; listed E	MB,ON,QC
Mountain Plover	*Charadrius*	*montanus*				AB,SK
Northern Bobwhite	*Colinus*	*virginianus*			1994	ON
Peregrine Falcon (*anatum*)	*Falco*	*peregrinus*	*anatum*		1979	ALL EXCEPT PEI
Piping Plover	*Charadrius*	*melodus*			T 1978; uplisted to E 1985	AB,MB,NB,NF,ON,PE,QC,SK
Prothonotary Warbler	*Protonotaria*	*citrea*			V 1984; uplisted to E 1996	ON
Sage Grouse	*Centrocercus*	*urophasianus*	*urophasianus*		T 1997; E 1998	AB,SK
Sage Thrasher	*Oreoscoptes*	*montanus*			1992	AB,BC,SK
Spotted Owl	*Strix*	*occidentalis*			1986	BC
Whooping Crane	*Grus*	*americana*			1978	NT
REPTILES						
Blue Racer Snake	*Coluber*	*constrictor*	*foxii*		1991	
Lake Erie Water Snake	*Nerodia*	*sipedon*	*insularum*		1991	ON
Leatherback Turtle	*Dermochelys*	*coriacea*			1981	
AMPHIBIANS						
Cricket Frog	*Acris*	*crepitans*	*blanchardi*		1990	ON
Northern Leopard Frog	*Rana*	*pipiens*		BC (Southern Mountain)	1998	BC,AB
FISH						
Acadian Whitefish	*Coregonus*	*huntsmani*			1984	NS
Aurora Trout	*Salvelinus*	*fontinalis*	*timagamiensis*		1987	ON
Nooksack Dace	*Rhinichthys*	sp.			1996	BC
Salish Sucker	*Catostomus*	sp.			1986	BC
INVERTEBRATES						
Hotwater Physa	*Physella*	*wrighti*			1998	BC
Maritime Ringlet Butterfly	*Coenonympha*	*tullia*	*nipisiquit*		1997	NB
PLANTS						
Bearded Owl-clover	*Triphysaria*	*versicolor*	*versicolor*		1998	BC
Bluehearts	*Buchnera*	*americana*			T 1985; E 1998	ON
Cucumber Tree	*Magnolia*	*acuminata*			1984	ON
Deltoid Balsamroot	*Balsamorhiza*	*deltoidea*			1996	BC
Drooping Trillium	*Trillium*	*flexipes*			1996	ON

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Eastern Mountain Avens	*Geum*	*peckii*			1986	NS
Eastern Prickly Pear Cactus	*Opuntia*	*humifusa*			E 1985; confirmed 1998	ON
Engelmann's Quillwort	*Isoetes*	*engelmannii*			1993	ON
Furbish's Lousewort	*Pedicularis*	*furbishiae*			E 1980; confirmed 1998	NB
Gattinger's Agalinus	*Agalinus*	*gattingeri*			1988	ON
Heart-leaved Plantain	*Plantago*	*cordata*			E 1985; confirmed 1998	ON
Hoary Mountain Mint	*Pycnanthemum*	*incanum*			E 1986: confirmed 1998	ON
Large Whorled Pogonia	*Isotria*	*verticillata*			E 1986; confirmed 1998	ON
Long's Braya	*Braya*	*longii*			1997	NF
Pink Coreopsis	*Coreopsis*	*rosea*			1984	NS
Pink Milkwort	*Polygala*	*incarnata*			E 1984; confirmed 1998	ON
Prairie Lupine	*Lupinus*	*lepidus*	*lepidus*		1996	BC
Seaside Birds-foot Lotus	*Lotus*	*formosissimus*			1996	BC
Skinner's Agalinus	*Agalinus*	*skinneriana*			1988	ON
Slender Bush Clover	*Lespedeza*	*virginica*			1986	ON
Slender Mouse-ear-cress	*Halimolobos*	*virgata*			1986	AB,SK
Small White Lady's Slipper	*Cypripedium*	*candidum*			1981	ON,MB
Small Whorled Pogonla	*Isotria*	*medeoloides*			E 1982; confirmed 1998	ON
Southern Maidenhair Fern	*Adiantum*	*capillus-veneris*			E 1984; confirmed 1998	BC
Spotted Wintergreen	*Chimaphila*	*maculata*			E 1985; confirmed 1998	ON
Thread-leaved Sundew	*Drosera*	*filiformis*			1991	NS
Tiny Cryptanthe	*Cryptantha*	*minima*			1998	AB,SK
Water-pennywort	*Hydrocotyle*	*umbellata*			1985	NS
Water-plantain Buttercup	*Ranunculus*	*alismaefolius*	*alismaefolius*		1996	BC
Western Prairie White Fringed Orchid	*Platanthera*	*praeclara*			1993	MB
White Prairie Gentian	*Gentiana*	*alba*			1991	ON
Wood Poppy	*Stylophorum*	*diphyllum*			1993	ON
LICHENS						
Seaside Centipede Lichen	*Heterodermia*	*stitchensis*			1996	BC
			THREATENED (T)			
MAMMALS						
Harbour Porpoise	*Phocoena*	*phocoena*		NW Atlantic	T in 1990; confirmed 1991	
Humpback Whale	*Megaptera*	*novaeangliae*		NW Pacific	T 1982; confirmed 1985	
Pacific Water Shrew	*Sorex*	*bendirii*			1994	BC
Peary Caribou	*Rangifer*	*tarandus*	*pearyi*	Low Arctic	T 1979; split and designated T; 1991	NT
Sea Otter	*Enhydra*	*lutris*			E 1978; confirmed 1986; T 1996	BC
Townsend's Mole	*Scapanus*	*townsendii*			1996	BC
White Whale (Beluga)	*Delphinapterus*	*leucas*		E Hudson Bay	1988	
Wood Bison	*Bison*	*bison*	*athabascae*		E in 1978; downlisted to T 1988	AB,BC,NT,YT
Woodland Caribou	*Rangifer*	*tarandus*	*caribou*	Gaspe	1984	QC
BIRDS						
Hooded Warbler	*Wilsonia*	*citrana*			1994	ON
Loggerhead Shrike	*Lanius*	*ludovicianus*	*excubitorides*		T 1986; split 1991; listed T	AB,MB,SK
Marbled Murrelet	*Brachyramphus*	*marmoratus*			1990	BC

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Roseate Tern	*Sterna*	*dougallii*			1986	NS,QC
White-headed Woodpecker	*Picoides*	*albolarvatus*			1992	BC
Yellow-breasted Chat	*Icteris*	*virens*	*auricollis*	BC population	1994	BC
REPTILES						
Black Rat Snake	*Elaphe*	*obsoleta*	*obsoleta*		1998	ON
Blanding's Turtle	*Emydoidea*	*blandingi*		Nova Scotia	1993	NS
Eastern Massasauga Rattlesnake	*Sistrurus*	*catenatus*	*catenatus*		1991	ON
Spiny Softshell Turtle	*Apolone*	*spinifera*			1991	ON,QC
FISH						
Black Redhorse	*Moxostoma*	*duquesnei*			1988	QC
Blackfin Cisco	*Coregonus*	*nigripinnis*			1988	ON
Channel Darter	*Percina*	*copelandi*			1993	ON,QC
Copper Redhorse	*Moxostoma*	*hubbsi*			1987	QC
Eastern Sand Darter	*Ammocrypta*	*pellucida*			1994	ON,QC
Enos Lake Stickleback	*Gasterosteus*	sp.			1988	BC
Great Lakes Deepwater Sculpin	*Myoxocephalus*	*thompsoni*			1987	AB,MB,NT,ON,QC,SK
Lake Simcoe Whitefish	*Coregonus*	*clupeaformis*			1987	ON
Lake Utopia Dwarf Smelt	*Osmerus*	sp.			1998	NB
Margined Madtom	*Noturus*	*insignis*			1989	ON,QC
Shorthead Sculpin	*Cottus*	*confusus*			1984	BC
Shortjaw Cisco	*Coregonus*	*zenithicus*			1987	AB,MB,NT,ON,SK
Shortnose Cisco	*Coregonus*	*reighardi*			1987	ON
Texada Stickleback	*Gasterosteus*	benthic form			1998	BC
Texada Stickleback	*Gasterosteus*	limnetic form			1998	BC
INVERTEBRATES						
Banff Springs Snail	*Physella*	*johnsoni*			1997	AB
PLANTS						
American Chestnut	*Castanea*	*dentata*			1987	ON
American Ginseng	*Panax*	*quinquefolium*			1988	ON,QC
American Water-willow	*Justicia*	*americana*			1984	ON,QC
Anticosti Aster	*Aster*	*anticostensis*			1990	NB,QC
Athabasca Thrift	*Armeria*	*maritima*	*interior*		1981	SK
Birds-foot Violet	*Viola*	*pedata*			1990	ON
Blue Ash	*Fraxinus*	*quadrangulata*			1983	ON
Blunt-lobed Woodsia	*Woodsia*	*obtusa*			1994	ON,QC
Colicroot	*Aletris*	*farinosa*			1988	ON
Deerberry	*Vaccinium*	*stamineum*			1994	ON
False Hop Sedge	*Carex*	*lupuliformis*			1997	ON,QC
Fernald's Braya	*Braya*	*fernaldii*			1997	NF
Goat's-rue	*Tephrosia*	*virginiana*			1996	ON
Golden Crest	*Lophiola*	*aurea*			1987	NS
Golden Paintbrush	*Castilleja*	*levisecta*			1995	BC
Golden Seal	*Hydrastis*	*canadensis*			1991	ON
Hairy Prairie Clover	*Dalea*	*villosa*	*villosa*		1998	SK, MB
Kentucky Coffee Tree	*Gymonocladus*	*dioica*			1983	ON

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Mosquito Fern	*Azolla*	*mexicana*			T 1984; confirmed 1998	BC
Nodding Pogonia	*Triphora*	*trianthophora*			1988	ON
Pitcher's Thistle	*Cirsium*	*pitcheri*			1988	ON
Plymouth Gentian	*Sabatia*	*kennedyana*			1984	NS
Purple Twayblade	*Liparis*	*liliifolia*			1989	ON
Red Mulberry	*Morus*	*rubra*			1987	ON
Redroot	*Lachnanthes*	*caroliana*			1994	NS
Round-leaved Greenbrier	*Smilax*	*rotundifolia*		Ontario	1994	ON
Sand Verbena	*Abronia*	*micrantha*			1992	AB,SK
Small-flowered Lipocarpha	*Lipocarpha*	*micrantha*			1992	BC,ON
Sweet Pepperbush	*Clethra*	*alnifolia*			T 1986; confirmed 1998	NS
Tyrrell's Willow	*Salix*	*planifolia*	*tyrrellii*		1981	SK
Western Blue Flag	*Iris*	*missouriensis*			1990	AB,BC
Western Spiderwort	*Tradescantia*	*occidentalis*			1992	AB,MB
White Wood Aster	*Aster*	*divaricatus*			1995	ON,QC
White-top Aster	*Aster*	*curtus*			1996	BC
Yellow Montane Violet	*Viola*	*praemorsa*	*praemorsa*		1995	BC
van Brunt's Jacob's Ladder	*Polemonium*	*van-bruntiae*			1994	QC
MOSSES						
Apple Moss	*Bartramia*	*stricta*			1997	BC
				VULNERABLE (V)		
MAMMALS						
Black-tailed Prairie Dog	*Cynomys*	*ludovicianus*			V in 1978; confirmed 1988	SK
Blue Whale	*Balaenoptera*	*musculus*			1983	
Eastern Mole	*Scalopus*	*aquaticus*			1980; confirmed 1998	ON
Fin Whale	*Balaenoptera*	*physalus*			1987	
Fringed Myotis	*Myotis*	*thysanodes*			1988	BC
Gaspe Shrew	*Sorex*	*gaspensis*			1988	NB,NS,QC
Grey Fox	*Urocyon*	*cinereoargenteus*			1979	AB,MB,ON,QC
Grizzly Bear	*Ursus*	*arctos*		All but Prairie	NAR 1979; split and listed V 1991	AB,BC,NT,YT
Harbour Seal (Lac de loups marins)	*Phoca*	*vitulina*	*mellonae*		1996	QC
Humpback Whale	*Megaptera*	*novaeangliae*		W North Atlantic	T 1982; downlisted to V 1985	
Keen's Long-eared Bat	*Myotis*	*keenii*			1988	BC
Northern Bottlenose Whale	*Hyperoodon*	*ampullatus*		Gully population	1996	
Nuttall's Cottontail Rabbit	*Sylvilagus*	*nuttallii*	*nuttallii*		1994	BC
Ord's Kangaroo Rat	*Dipodomys*	*ordii*			1995	AB,SK
Pallid Bat	*Antrozous*	*pallidus*			1988	BC
Polar Bear	*Ursus*	*maritimus*			NAR 1986; uplisted to V 1991	NT,MB,NF,ON,QC
Queen Charlotte Ermine	*Mustela*	*erminea*	*haidarum*		1984	BC
Southern Flying Squirrel	*Glaucomys*	*volans*			1988	NB,NS,ON,QC
Sowerby's Beaked Whale	*Mesoplodon*	*bidens*			1989	
Spotted Bat	*Euderma*	*maculatum*			1988	BC
Western Harvest Mouse	*Reithrodontomys*	*megalotis*	*megalotis*		1994	BC
White Whale (Beluga)	*Delphinapterus*	*leucas*		E High Arctic/Baffin population	1992	

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Wolverine	*Gulo*	*gulo*		Western population	RARE 1982; split and designated V; 1989	AB,BC,MB,NT,ON,SK,YT
Woodland Caribou	*Rangifer*	*tarandus*	*caribou*	Western population	1984	AB,BC,MB,NT,ON,SK
Woodland Vole	*Microtus*	*pinetorum*			1998	ON,QC
BIRDS						
Ancient Murrelet	*Synthliboramphus*	*antiquus*			1993	BC
Barn Owl	*Tyto*	*alba*			1984	BC,ON
Caspian Tern	*Sterna*	*caspia*			1978	AB,BC,MB,NF,NT,ON,QC,SK
Cerulean Warbler	*Dendroica*	*cerulea*			1993	ON,QC
Ferruginous Hawk	*Buteo*	*regalis*			T 1980; downlisted to V 1995	AB,SK,MB
Flammulated Owl	*Otus*	*flammeolus*			1988	BC
Ipswich Sparrow	*Passerculus*	*sandwichensis*	*princeps*		1979	NS
Ivory Gull	*Pagophila*	*eburnea*			V in 1981; confirmed 1996	BC,MB,NF,NT,QC
Least Bittern	*Ixobrychus*	*exilis*			1988	MB,NB,ON,QC
Long-billed Curlew	*Numenius*	*americana*			1992	AB,BC,SK
Louisiana Waterthrush	*Seiurus*	*motacilla*			V 1991; confirmed 1996	ON
Pacific Great Blue Heron	*Ardea*	*herodias*	*fannini*		1997	BC
Peregrine Falcon (Peale's)	*Falco*	*perigrinus*	*pealei*		1978	BC
Peregrine Falcon (Tundra)	*Falco*	*perigrinus*	*tundrius*		T 1978; downlisted to V 1992	NF,NT,QC,YT
Prairie Warbler	*Dendroica*	*discolor*			1985	ON
Queen Charlotte Goshawk	*Accipter*	*gentilis*	*laingi*		1995	BC
Red-headed Woodpecker	*Melanerpes*	*erythrocephalus*			1996	MB,ON,QC,SK
Red-shouldered Hawk	*Buteo*	*lineatus*			V 1983; confirmed 1996	ON,QC
Ross' Gull	*Rhodostethia*	*rosea*			V 1981; confirmed 1996	MB,NT
Short-eared Owl	*Asio*	*flammeus*			1994	ALL
Yellow-breasted Chat	*Icteria*	*virens*	*virens*		1994	ON
REPTILES						
Eastern Hognose Snake	*Heterodon*	*platirhinos*			1997	ON
Eastern Short-horned Lizard	*Phrynosoma*	*hernandezi*			1992	AB,SK
Eastern Yellowbelly Racer	*Coluber*	*constrictor*	*flaviventris*		1991	SK
Five-lined Skink	*Eumeces*	*fasciatus*			1998	ON
Northern Prairie Skink	*Eumeces*	*septentrionalis*	*septentrionalis*		1989	MB
Spotted Turtle	*Clemmys*	*guttata*			1991	ON,QC
Wood Turtle	*Clemmys*	*insculpta*			1996	ON,QC,NS,NB
AMPHIBIANS						
Coeur d'Alene Salamander	*Plethodon*	*idahoensis*			1998	BC
Fowler's Toad	*Bufo*	*fowleri*			1996	ON
Giant Pacific Salamander	*Dicamptodon*	*tennebrosus*			1989	BC
Great Basin Spadefoot Toad	*Spea*	*intermontana*			1998	BC
Mountain Dusky Salamander	*Desmognathus*	*ochrophaeus*			1998	QC
Northern Leopard Frog	*Rana*	*pipiens*		Prairie	1998	AB,SK,MB
Smallmouth Salamander	*Ambystoma*	*texanum*			1991	ON
FISH						
Atlantic Cod	*Gadus*	*morhua*			1998	
Banded Killifish	*Fundulus*	*diaphanus*		Newfoundland	1989	NF

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Bering Wolffish	*Anarhichas*	*orientalis*			1989	
Bigmouth Buffalo	*Ictiobus*	*cyprinellus*			1989	MB,ON,SK
Bigmouth Shiner	*Notropis*	*dorsalis*			1985	MB
Black Buffalo	*Ictiobus*	*niger*			1989	ON
Blackline Prickleback	*Acantholumpenus*	*mackayi*			1989	
Blackstripe Topminnow	*Fundulus*	*notatus*			1985	ON
Brindled Madtom	*Notorus*	*miurus*			1985	ON
Charlotte Unarmoured Stickleback	*Gasterosteus*	*aculeatus*			1983	BC
Chestnut Lamprey	*Ichthyomyzon*	*castaneus*			1991	MB,SK
Cultus Pygmy Sculpin	*Cottus*	sp.			1997	BC
Fourhorn Sculpin	*Myoxocephalus*	*quadricornis*		Arctic freshwater form	1989	NT
Giant Stickleback	*Gasterosteus*	sp.			1980	BC
Green Sturgeon	*Acipenser*	*medirostris*			1987	BC
Greenside Darter	*Etheostoma*	*blennioides*			1990	ON
Kiyi	*Coregonus*	*kiyi*			1988	ON
Lake Chubsucker	*Erimyzon*	*sucetta*			1994	ON
Lake Lamprey	*Lampetra*	*macrostoma*			V 1986; confirmed 1998	BC
Northern Brook Lamprey	*Ichthyomyzon*	*fossor*			1991	MB,ON,QC
Northern Madtom	*Noturus*	*stigmosus*			I 1993; V 1998	ON
Orangespotted Sunfish	*Lepomis*	*humilus*			1989	ON
Pacific Sardine	*Sardinops*	*sagax*			1987	
Pugnose Minnow	*Opsopoeodus*	*emilae*			1985	ON
Pugnose Shiner	*Notropis*	*anogenus*			1985	ON
Redbreast Sunfish	*Lepomis*	*auritus*			1989	NB
Redside Dace	*Clinostomus*	*elongatus*			1987	ON
River Redhorse	*Moxostoma*	*carinatum*			V 1993; confirmed 1987	ON,QC
Rosyface Shiner	*Notropis*	*rubellus*		Manitoba	1994	MB
Shortnose Sturgeon	*Acipenser*	*brevirostrum*			1980	NB
Sliver Chub	*Macrhybopsis*	*storeriana*			1985	MB,ON
Sliver Shiner	*Notropis*	*photogenis*			V in 1983; confirmed 1987	ON
Speckled Dace	*Rhinichthys*	*osculus*			1980	BC
Spotted Gar	*Lepisosteus*	*oculatus*			V in 1983; confirmed 1994	ON
Spotted Sucker	*Minytrema*	*melanops*			V in 1983; confirmed 1994	ON
Spring Cisco	*Coregonus*	sp.			1992	QC
Squanga Whitefish	*Coregonus*	sp.			1987	YT
Umatilla Dace	*Rhinichthys*	*umatilla*			1988	BC
Warmouth	*Lepomis*	*gulosus*			1994	ON
Western Silvery Minnow	*Hybognathus*	*argyritis*			1997	AB
White Sturgeon	*Acipenser*	*transmontanus*			1990	BC
INVERTEBRATES						
Monarch	*Danaus*	*plexippus*			1997	ALL
PLANTS						
American Columbo	*Frasera*	*caroliniensis*			1993	ON
Bathurst Aster	*Aster*	*subulatus*	*obtusifolius*		1992	NB

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Bolander's Quillwort	*Isoetes*	*bolanderi*			1995	AB
Branched Bartonia	*Bartonia*	*paniculata*			1992	ON
Broad Beech Fern	*Phegopteris*	*hexagonaptera*			1983	ON,QC
Buffalograss	*Buchloe*	*dacyloides*			1998	SK,MB
Climbing Prairie Rose	*Rosa*	*setigera*			1986	ON
Coastal Wood Fern	*Dryopteris*	*arguta*			1998	BC
Dense Blazing Star	*Liatris*	*spicata*			1988	ON
Dwarf Hackberry	*Celtis*	*tenuifolia*			1985	ON
Eastern Prairie White Fringed Orchid	*Plantanthera*	*leucophaea*			1986	ON
False Rue-Anemone	*Isopyrum*	*biternatum*			1990	ON
Fernald's Milk-vetch	*Astragalus*	*robbinsii*	*fernaldii*		1997	NF,QC
Few-flowered Club-rush	*Scirpus*	*verecundis*			1986	ON
Giant Helleborine	*Epipactis*	*gigantea*			T 1984; V 1998	BC
Green Dragon	*Arisaema*	*dracontium*			1984	ON,QC
Gulf of St. Lawrence Aster	*Aster*	*laurentianus*			1989	NB,PE,QC
Hare-footed Locoweed	*Oxytropis*	*lagopus*			1995	AB
Hill's Pondweed	*Potomogeton*	*hillii*			1986	ON
Hop Tree	*Ptelea*	*trifoliata*			1984	ON,QC
Indian Plantain	*Cacalia*	*plantaginea*			1988	ON
Lilaeopsis	*Lilaeopsis*	*chinensis*			1987	NS
Long's Bulrush	*Scirpus*	*longii*			1994	NS
Macoun's Meadowfoam	*Limnanthes*	*macounii*			1988	BC
New Jersey Rush	*Juncus*	*caesariensis*			1992	NS
Phantom Orchid	*Cephalanthera*	*austinae*			1992	BC
Provancher's Fleabane	*Erigeron*	*philadelphicus*	*provancheri*		1992	QC
Shumard Oak	*Quercus*	*shumardii*			1984	ON
Smooth Goosefoot	*Chenopodium*	*subglabrum*			1992	AB,MB,SK
Soapweed	*Yucca*	*glauca*			1985	AB
Swamp Rose Mallow	*Hibiscus*	*moscheutos*			1987	ON
Victorin's Gentian	*Gentiana*	*victorinii*			1987	QC
Victorin's Water Hemlock	*Cicuta*	*maculata*	*victorinii*		1987	QC
Western Silver-leaf Aster	*Virgulus*	*sericeus*			1988	MB,ON
Wild Hyacinth	*Camassia*	*scilloides*			1990	ON
LICHENS						
Cryptic Paw Lichen	*Nephroma*	*occultum*			1995	BC
Oldgrowth Specklebelly Lichen	*Pseudocyphellaria*	*rainierensis*			1996	BC
Seaside Bone Lichen	*Hypogymnia*	*heterophylla*			1996	BC
			NOT AT RISK (NAR)			
MAMMALS						
American Badger	*Taxidea*	*taxus*			1979	AB,BC,MB,ON,SK
American Black Bear	*Ursus*	*americanus*			1998	ALL
Atlantic Walrus	*Odobenus*	*rosmarus*		E Arctic	1987	
Atlantic White-sided Dolphin	*Lagenorhynchus*	*acutus*			1991	
Baird's Beaked Whale	*Berardius*	*bairdii*			1992	
Bearded Seal	*Erignathus*	*barbatus*			1994	

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Blainville's Beaked Whale	*Mesoplodon*	*densirostris*			1989	
Bottlenose Dolphin	*Tursiops*	*truncatus*			1993	
California Sea Lion	*Zalophis*	*californianus*			1987	
Cascade Mantled Ground Squirrel	*Spermophilus*	*saturatus*			1992	BC
Common Dolphin	*Delphinus*	*delphis*			1991	
Cuvier's Beaked Whale	*Ziphius*	*cavirostris*			1990	
Dall's Porpoise	*Phocoenoides*	*dalli*			1989	
False Killer Whale	*Pseudorca*	*crassidens*			1990	
Fox Squirrel	*Sciurus*	*niger*			1979	MB,ON
Gray Whale	*Eschrichtius*	*robustus*		NE Pacific	1987	
Hooded Seal	*Cystophora*	*cristata*			1986	
Hubb's Beaked Whale	*Mesoplodon*	*carlhubbsi*			1989	
Long-finned Pilot Whale	*Globicephala*	*melas*			1994	
Lynx	*Lynx*	*canadensis*			1989	ALL EXCEPT PE
Mountain Beaver	*Aplodontia*	*rufa*			1984	BC
Narwhal	*Monodon*	*monoceros*			NAR 1986; confirmed 1987	
Northern Bottlenose Whale	*Hyperoodon*	*ampullatus*			1993	
Northern Elephant Seal	*Mirounga*	*angustirostris*			1986	
Northern Fur Seal	*Callorhinus*	*ursinus*			1996	
Northern Right Whale Dolphin	*Lissodelphis*	*borealis*			1990	
Nuttall's Cottontail	*Sylvilagus*	*nutallii*	*pinetis*		NAR 1991; confirmed 1994	AB,SK
Pacific White-sided Dolphin	*Lagenorhynchus*	*obliquens*			1990	
Plains Pocket Gopher	*Geomys*	*bursarius*			V 1979; N 1998	MB
Prairie Long-tailed Weasel	*Mustela*	*frenata*	*longicauda*		T 1982; delisted 1993	AB,MB,SK
Pygmy Sperm Whale	*Kogia*	*breviceps*			1994	
Ringed Seal	*Phoca*	*hispida*			1989	
Risso's Dolphin	*Grampus*	*griseus*			1990	
Short-finned Pilot Whale	*Globicephala*	*macrorhynchus*			1993	
Sperm Whale	*Physeter*	*macrocephalus*			1996	
Stejneger's Beaked Whale	*Mesoplodon*	*stejnegeri*			1989	
Stellar Sea Lion	*Eumetopias*	*jubatus*			1987	
Striped Dolphin	*Stenalla*	*coeruleoalba*			1993	
True's Beaked Whale	*Mesoplodon*	*mirus*			1989	
White-beaked Dolphin	*Lagenorhynchus*	*albirostris*			1998	
White Whale (Beluga)	*Delphinapterus*	*leucas*		W Hudson Bay	1993	
White Whale (Beluga)	*Delphinapterus*	*leucas*		Beaufort/Arctic Ocean	1985	
Woodland Caribou	*Rangifer*	*tarandus*	*caribou*	Labrador/Ungava	1984	NF
Woodland Caribou	*Rangifer*	*tarandus*	*caribou*	Newfoundland	1984	NF,QC
BIRDS						
American Coot	*Fulica*	*americana*			1991	ALL EXCEPT NF
American White Pelican	*Pelecanus*	*erythrorhynchos*			T in 1978; delisted 1987	AB,BC,MB,ON,SK
Baird's Sparrow	*Ammodramus*	*bairdii*			T 1989; delisted 1996	AB,MB,SK
Bald Eagle	*Haliaeetus*	*leucocephalus*			1984	ALL

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Black Tern	*Chlidonias*	*niger*			NAR 1978; confirmed 1996	AB,BC,MB,NB,NS,NT,ON,QC,SK
Boreal Owl	*Aegolius*	*funereus*			1995	ALL
Canyon Wren	*Catherpes*	*mexicanus*			1992	BC
Common Loon	*Gavia*	*immer*			1997	ALL
Common Tern	*Sterna*	*hirundo*			1998	AB,SK,MB,ON,QC,NS,NB,NF
Cooper's Hawk	*Accipitor*	*cooperii*			V in 1983; delisted 1996	AB,BC,MB,NB,NS,ON,QC,SK
Double-crested Cormorant	*Phalocrocorax*	*auritus*			1978	ALL
Eastern Bluebird	*Sialia*	*sialis*			V in 1984; delisted 1996	MB,NB,NS,ON,QC,SK
Eastern Screech-owl	*Otus*	*asio*			1986	MB,ON,QC,SK
Golden Eagle	*Aquila*	*chrysaetos*			NAR 1987; confirmed 1996	ALL
Gray Flycatcher	*Empidonax*	*wrightii*			1992	BC
Great Gray Owl	*Strix*	*nebulosa*			V in 1979; delisted 1996	AB,BC,MB,NT,ON,QC,SK,YT
Greater Sandhill Crane	*Grus*	*canadensis*	*tabida*		1989	BC,MB,ON
Gyrfalcon	*Falco*	*rusticolus*			NAR 1978; confirmed 1987	AB,BC,NS,NT,ON,QC,SK,YT,PE,NF
Merlin	*Falco*	*columbarius*			1985	ALL
Nelson's Sharp-tailed Sparrow	*Ammodramus*	*nelsoni*			1998	AB,SK,MB,NS,NB
Northern Goshawk	*Accipiter*	*gentilis*	*atricapillus*		1995	ALL
Northern Harrier	*Circus*	*cyaneus*			1993	ALL
Northern Hawk Owl	*Surnia*	*ulula*			1992	AB,BC,MB,NB,NF,NT,ON,QC,SK,YT
Prairie Falcon	*Falco*	*mexicanus*			NAR 1978; confirmed 1982,1996	AB,BC,SK
Red-necked Grebe	*Podiceps*	*grisegena*			1982	ALL EXCEPT PEI,NB
Red-tailed Hawk	*Buteo*	*jamaicensis*			1995	ALL
Rough-legged Hawk	*Buteo*	*lagopus*			1995	AB,BC,MB,NB,NF,NT,ON,QC,SK,YT
Sedge Wren	*Cistothurus*	*platensis*			1993	AB,MB,NB,ON,QC,SK
Sharp-shinned Hawk	*Accipiter*	*striatus*			NAR 1996, confirmed 1997	ALL
Snowy Owl	*Nyctea*	*scandiaca*			1995	YT,NT,MB,QC,NF
Trumpeter Swan	*Cygnus*	*buccinator*			V 1978; delisted 1996	AB,BC,SK,YT,NT
Yellow-billed Loon	*Gavia*	*adamsii*			1997	AB,BC,MB,NT,QC,YT
Yellow-breasted Chat	*Icteria*	*virens*	*auricollis*	Prairie	1994	AB,SK
REPTILES						
Western Yellowbelly Racer	*Coluber*	*constrictor*	*mormon*		1991	BC
FISH						
Banded Killifish	*Fundulus*	*diaphanus*		Mainland	1989	MB,NB,NF,NS,ON,PE,QC
Blackchin Shiner	*Notropis*	*heterodon*			1994	MB,ON,QC
Bloater	*Coregonus*	*hoyi*			1988	ON
Blueback Herring	*Alosa*	*aestivalis*			1980	NB,NS
Bluntnose Minnow	*Pimephales*	*notatus*			1998	QC, ON,MB
Brook Silverside	*Labidesthes*	*sicculus*			1989	ON,QC
Central Stoneroller	*Campostoma*	*anomalum*			V 1985; NAR 1998	ON
Chain Pickeral	*Esox*	*niger*			1997	NB,NS,QC
Cutlips Minnow	*Exoglossum*	*maxillingua*			1994	ON,QC
Eastern Silvery Minnow	*Hybognathus*	*regius*			1997	ON,QC
Fourhorn Sculpin	*Myoxocephalus*	*quadricornis*		Saltwater form	1989	
Ghost Shiner	*Notropis*	*buchanani*			1993	ON

continued

APPENDIX 1. (*Continued*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
Golden Redhorse	*Moxostoma*	*erythrurum*			1989	MB,ON
Green Sunfish	*Lepomis*	*cyanellus*			1987	ON
Hornyhead Chub	*Nocomis*	*biguttatus*			1988	MB,ON
Lake Sturgeon	*Acipenser*	*fulvescens*			1986	AB,MB,ON,QC,SK
Least Darter	*Etheostoma*	*microperca*			1989	ON
Leopard Dace	*Rhinichthys*	*falcatus*			1990	BC
Longear Sunfish	*Lepomis*	*megalotis*			1987	ON,QC
Mountain Sucker	*Catostomus*	*platyrhynchus*			1991	AB,BC,SK
Redfin Pickerel	*Esox*	*americanus*	*americanus*		1998	MB
Redfin Shiner	*Lythrurus*	*umbratilis*			1988	ON
River Chub	*Nocomis*	*micropogon*			1988	ON
River Darter	*Percina*	*shumardi*			1989	MB,ON
Rosyface Shiner	*Notropis*	*rubellus*			1994	ON,QC
Spoonhead Sculpin	*Cottus*	*ricei*			1989	AB,BC,MB,NT,ON,QC,SK,YT
Striped Shiner	*Luxilus*	*chrysocephalus*			1993	ON
Tesselated Darter	*Etheostoma*	*olmstedi*			1993	ON,QC
Y-Prickleback	*Allolumpenus*	*hypochromus*			1991	BC
PLANTS						
Blue Phlox	*Phlox*	*alyssifolia*			1996	AB,BC,SK
Dwarf Fleabane	*Erigeron*	*radicatus*			1996	AB,SK
False Mermaid	*Floerkea*	*proserpinacoides*			1984	NS,ON,QC
Fameflower	*Talinum*	*sediforme*			1990	BC
Large-flowered Brickellia	*Brickellia*	*grandiflora*			1996	AB,BC
MacLean's Goldenweed	*Haplopappus*	*macleanii*			1997	YT
Narrow-leafed Wallflower	*Erysimum*	*angustatum*			1993	YT
Nebraska Sedge	*Carex*	*nebrascensis*			1995	AB
Pacific Rhododendron	*Rhododendron*	*macrophyllum*			1997	BC
Rush Pink	*Stephanomeria*	*runcinata*			1996	AB,SK
Sand Stichwort	*Stellaria*	*arenicola*			1992	AB,SK
Slender Wooly-heads	*Psilicarphus*	*tennellus*	*tenellus*		1996	BC
Wood's Sagebrush	*Artemisia*	*rupestris*	*woodii*		1997	BC
Yukon Aster	*Aster*	*yukonensis*			1996	NT,YT
				INDETERMINATE (I)		
MAMMALS						
Cougar	*Felis*	*concolor*		Eastern	E 1978; I 1998	NB,NS,ON,QC
Dwarf Sperm Whale	*Kogia*	*simus*			1997	
Harbour Porpoise	*Phocoena*	*phocoena*		NE Pacific	1991	
Sagebrush Vole	*Lemmiscus*	*curtatus*			1996	AB,SK
Western Harvest Mouse	*Reithrodontomys*	*megalotis*	*dychei*		1994	AB
BIRDS						
Common Poorwill	*Phalaenoptilus*	*nutallii*			1993	AB,BC,SK
Forster's Tern	*Sterna*	*forsteri*			1996	AB,BC,MB,ON,SK
Western Screech Owl	*Otus*	*kennicottii*			1995	BC

continued

APPENDIX 1. (*Concluded*)

Common Name	Genus	Species	Subspecies/ Variety	Population	Listing History	Provinces of Occurrence
FISH						
Bering Cisco	*Coregonus*	*laurettae*			1990	YT
Chiselmouth	*Acrocheilus*	*alutaceus*			1997	BC
Darktail Lamprey	*Lethenteron*	*alaskense*			1990	NT
Flathead Catfish	*Pylodictis*	*olivaris*			1993	ON
Pixie Poacher	*Ocella*	*impi*			1991	BC
Spinynose Sculpin	*Asemicthys*	*taylori*			1997	
INVERTEBRATES						
Gatineau Tadpole Snail	*Physella*	*parkeri*	*latchfordi*		1997	ON(?),QC
PLANTS						
Impoverished Pinweed	*Lechea*	*intermedia*	*depauperata*		1997	SK
Kananaskis Whitlow-Cress	*Draba*	*kananaskis*			1992	AB
Little Barley	*Hordeum*	*pusillum*			1993	AB
Rabbit-brush Goldenweed	*Ericameria*	*bloomeri*			1997	BC

Editor's Note:

In Appendix 1, amphibian and reptile common and scientific names have been updated from those used in original COSEWIC reports to conform with more recent usage:

Collins, Joseph T. 1997. Standard common and current scientific names for North American amphibians and reptiles. Fourth edition. Society for the Study of Amphibians and Reptiles, Herpetological Circular number 25. 40 pages.

Green, David M. *Editor.* 1997. Amphibians in decline: Canadian studies of a global problem. Society for the Study of Amphibians and Reptiles, Herpetological Conservation number 1. xiii + 338 pages.

Powell, G. Lawrence, and **Anthony P. Russell.** 1998. The status of short-horned lizards, *Phrynosoma douglasi* and *P. hernandezi*, in Canada. Canadian Field-Naturalist 112(1): 1–16.

The additions made in at the April 1999 COSWEIC meeting will appear in 113(2) July-September of *The Canadian Field-Naturalist* in the Notices section under "Species at Risk, 1999".

A Tribute to Raymond John Moore, 1918-1998

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Mulligan, Gerald A. 1999. A tribute to Raymond John Moore, 1918-1998. Canadian Field-Naturalist 113(2): 342–344.

Raymond (Ray) John Moore died at Laurier Manor, in Ottawa, on Wednesday, 2 September, 1998. He was Treasurer of the Ottawa Field-Naturalists' Club from 1950 to 1957. Although Ray was hardly an active naturalist, he took pride in his support of the OFNC both as a long-time member and during his term as Treasurer. He loved to say that he was able to identify all species of birds, using his dichotomous key: feet webbed-ducks; feet unwebbed-chickens. Ray was an overly shy person, who most often communicated with friends and colleagues by means of hand-written notes.

Ray received his B.A. from McMaster University and his M.A., in 1943, and Ph.D., in 1946, from the

University of Virginia. He worked with Agriculture Canada, at the Central Experimental Farm, from 1943 to 1977.

Ray was a first-class plant cytologist who very generously shared his knowledge with others. I was a fortunate recipient. Early in his scientific career, he worked on the ornamental shrub *Buddleia*. After coming to the Central Experimental Farm, he worked extensively on the cytotaxonomy of the thistle genera *Cirsium* and *Carduus*. He was the editor of the World Index of Plant Chromosome Numbers for many years. He retired in 1977 because of his failing eyesight. He remained, until his death, a substantial supporter of Knox Presbyterian Church. His friends and former colleagues will miss Ray's shy impish humour.

Bibliography of R. J. Moore

Gaiser, L. O., M. Sutherland, and **R. J. Moore.** 1943. Cytological studies in *Martynia louisiana*. American Journal of Botany 30: 543–551.

Moore, R. J. 1946. Investigations on rubber-bearing plants. III. Development of normal and aborting seeds in *Asclepias syriaca* L. Canadian Journal of Research Section C, Botanical Science 24: 55–65.

Moore, R. J. 1946. Investigations on rubber-bearing plants. IV. Cytogenetic studies in *Asclepias* (Tourn.) L. Canadian Journal of Research Section C, Botanical Science 24: 66–73.

Moore, R. J. 1947. Cytotaxonomic studies in the Loganiaceae. I. Chromosome numbers and phylogeny in the Loganiaceae. American Journal of Botany 34: 527–538.

Moore, R. J. 1947. Investigations on rubber-bearing plants. V. Notes on the flower biology and pod yield of *Asclepias syriaca* L. Canadian Field-Naturalist 61: 40–46.

Moore, R. J. 1948. Cytotaxonomic studies in the Loganiacae. II. Embryology of *Polypremum procumbens* L. American Journal of Botany 35: 404–410.

Moore, R. J. 1949. Cytotaxonomic studies in the Loganiacae. III. Artificial hybrids in the genus *Buddleja* L. American Journal of Botany 36: 511–516.

Senn, H. A., W. M. Bowden, and **R. J. Moore.** 1949. La citotaxonomia del genera *Agropyron*. Lilloa 19: 119–120.

Moore, R. J. 1952. An interspecific hybrid in *Buddleja*. Journal of Heredity 43: 41–45.

Moore, R. J., and **D. R. Lindsay.** 1953. Fertility and polyploidy of *Euphorbia cyparissias* in Canada. Canadian Journal of Botany 31: 152–163.

Moore, R. J., and **C. Frankton.** 1954. Cytotaxonomy of three species of *Centaurea* adventive in Canada. Canadian Journal of Botany 32: 182–186.

Moore, R. J., and **G. A. Mulligan.** 1956. Natural hybridization between *Carduus nutans* and *Carduus acanthoides* in Ontario. Canadian Journal of Botany 34: 71–85.

Moore, R. J. 1958. The status of *Caragana boisii*. Baileya 6: 188–193.

Moore, R. J. 1958. Cytotaxonomy of *Euphorbia esula* in Canada and its hybrid with *Euphorbia cyparissias*. Canadian Journal of Botany 36: 547–559.

Moore, R. J. 1958. List of Canadian workers in the botanical sciences. Botany and Plant Pathology Division, Science Service, Canada Department of Agriculture, Ottawa. 47 pages.

Moore, R. J., and **G. A. Mulligan.** 1958. Study of natural hybridization between *Carduus acanthoides* and *Carduus nutans*. Proceedings of the International Congress of Genetics 2: 193.

Moore, R. J. 1959. The dog-strangling vine *Cynanchum medium*, its chromosome number and its occurrence in Canada. Canadian Field-Naturalist 73: 144–177.

Moore, R. J. 1959. A directory of botanists in Canada. Plant Research Institute, Research Branch, Canada Department of Agriculture, Ottawa. 99 pages.

Moore, R. J. 1960. Cyto-taxonomic notes on *Buddleia*. American Journal of Botany 47: 511–517.

Moore, R. J. 1961. Typification of the Linnaean species of *Caragana*. Canadian Journal of Botany 39: 1041–1044.

Moore, R. J. 1961. Behaviour of accessory chromosomes of *Secale cereale* in a *Secale cereale* ? *montanum* hybrid. Canadian Journal of Genetics and Cytology 3: 283–288.

Moore, R. J. 1961. Polyploidy, phylogeny, and photoperiodism in Old World *Buddleia*. Evolution 15: 272–280.

Frankton, C., and **R. J. Moore.** 1961. Cytotaxonomy, phylogeny, and Canadian distribution of *Cirsium undulatum* and *Cirsium flodmanii*. Canadian Journal of Botany 39: 21–33.

Mulligan, G. A., and **R. J. Moore.** 1961. Natural selection among hybrids between *Carduus acanthoides* and *C. nutans* in Ontario. Canadian Journal of Botany 39: 269–279.

Moore, R. J. 1962. On the origin of *Caragana sinica*. Journal of the Arnold Arbetum 43: 203–214.

Moore, R. J., and **C. Frankton.** 1962. Cytotaxonomic studies in the tribe Cynareae (Compositae). Canadian Journal of Botany 40: 282–293.

Moore, R. J., and **C. Frankton.** 1962. Cytotaxonomy and Canadian distribution of *Cirsium edule* and *Cirsium brevistylum*. Canadian Journal of Botany 40: 1187–1196.

Moore, R. J. 1963. *Caragana* × *prestonae* - *Caragana aurantiaca*? *Caragana frutex* hybrid. Canadian Journal of Genetics and Cytology 5: 119–126.

Moore, R. J. 1963. Karyotype evolution in *Caulophyllum*. Canadian Journal of Genetics and Cytology 5: 384–388.

Frankton, C., and **R. J. Moore.** 1963. Cytotaxonomy of *Cirsium muticum*, *Cirsium discolor*, and *Cirsium altissimum*. Canadian Journal of Botany 41: 74–84.

Frankton, C., and **R. J. Moore.** 1963. Cytotaxonomic notes on some *Cirsium* species of the Western United States. Canadian Journal of Botany 41: 1554–1567.

Moore, R. J., and **J. A. Calder.** 1964. Some chromosome numbers of *Carex* species of Canada and Alaska. Canadian Journal of Botany 42: 1387–1391.

Moore, R. J., and **C. Frankton.** 1964. A clarification of *Cirsium foliosum* and *Cirsium drummondii*. Canadian Journal of Botany 42: 452–461.

Moore, R. J., and **G. A. Mulligan.** 1964. Further studies on natural selection among hybrids of *Carduus acanthoides* and *Carduus nutans*. Canadian Journal of Botany 42: 1605–1613.

Moore, R. J. 1965. Colchicine tetraploid *Caragana arborescens*. Canadian Journal of Genetics and Cytology 7: 103–107.

Moore, R. J., and **C. Frankton.** 1965. Cytotaxonomy of *Cirsium hookerianum* and related species. Canadian Journal of Botany 43: 597–613.

Moore, R. J., and **W. F. Grant.** 1965. Lulu Odell Gaiser. Canadian Journal of Genetics and Cytology 7: 361–362.

Moore, R. J. *Compiler.* 1966. A survey of the vascular plants of Lambton Country, Ontario, by Lulu O. Gaiser. Plant Research Institute, Research Branch, Canada Department of Agriculture, Ottawa. 122 pages.

Moore, R. J., and **C. Frankton.** 1966. An evaluation of the status of *Cirsium pumilum* and *Cirsium hillii*. Canadian Journal of Botany 44: 581–595.

Moore, R. J. 1967. [Miscellaneous chromosome counts.] Page 66 *in* IOPB chromosome number reports IX. *Edited by* A. Löve. Taxon 16: 62–66.

Moore, R. J., and **C. Frankton.** 1967. Cytotaxonomy of foliose thistles (*Cirsium* spp. aff. *C. foliosum*) of western North America. Canadian Journal of Botany 45: 1733–1749.

Moore, R. J. 1967. Ornamental *Buddleia* for Canada. Greenhouse-Garden-Grass 6(3): 9–11.

Moore, R. J. 1968. Chromosome numbers and phylogeny in *Caragana* (Leguminosae). Canadian Journal of Botany 46: 1513–1522.

Moore, R. J. 1968. [Miscellaneous chromosome counts.] Page 421 *in* IOPB chromosome number reports XVIII. *Edited by* A. Löve. Taxon 17: 419–422.

Norman, E. M., and R. J. Moore. 1968. Notes on *Emorya* (Loganiaceae). South Western Naturalist 13: 137–142.

Moore, R. J. 1968. Genetics of *Caragana arborescens* 'LORBERGII'. Greenhouse-Garden-Grass 7(1): 4–9.

Moore, R. J. 1969. How weedy thistles came to Canada. Greenhouse- Garden-Grass 8(4): 1–2.

Moore, R. J., and **C. Frankton.** 1969. *Euphorbia* × *pseudoesula* (*E. cyparissias* × *E. esula*) in Canada. Canadian Field-Naturalist 83: 243–246.

Moore, R. J., and **C. Frankton.** 1969. Cytotaxonomy of some *Cirsium* species of the eastern United States, with a key to eastern species. Canadian Journal of Botany 47: 1257–1275.

Moore, R. J., and **J. H. Soper.** 1969. Directory of Canadian botanists: members of the Canadian Botanical Association, The Canadian Society of Plant Physiologists, The Canadian Phytopathological Society. Canadian Botanical Association, Ottawa. 32 pages.

Moore, R. J. 1970. History of the mycology and taxonomy sections. Greenhouse-Garden-Grass 9: 7–9.

Moore, R. J. 1972. Distribution of native and introduced knapweeds (*Centaurea*) in Canada and the United States. Rhodora 74: 331–346.

Moore, R. J. *Editor.* 1974. Index to plant chromosome numbers: 1967–1971. (Regnum Vegetabile 90.) A. Oosthoek & International Bureau Plant Taxonomy and Nomenclature, Utrecht, Netherlands. 539 pages.

Moore, R. J. *Editor.* 1974. Index to plant chromosome numbers for 1972. (Regnum Vegetabile 91.) Oosthoek, Scheltema & Holkema, Utrecht, Netherlands. 108 pages.

Moore, R. J., and **C. Frankton.** 1974. The *Cirsium arizonicum* complex of the southwestern United States. Canadian Journal of Botany 52: 543–551.

Moore, R. J., and **C. Frankton.** 1974. The thistles of Canada. Research Branch, Canada Department of Agriculture, Monograph Number 10. 112 pages.

Moore, R. J. 1975. The *Galium aparine* complex in Canada. Canadian Journal of Botany 53: 877–893.

Moore, R. J. 1975. The biology of Canadian weeds. 13. *Cirsium arvense* (L.) Scop. Canadian Journal of Plant Science 55: 1033–1048. [Reprinted 1979. Pages 146–161 *in* The biology of Canadian weeds, contributions 1–32. *Edited by* G. A. Mulligan. Agriculture Canada. Publication Number 1693. 380 pages.]

Moore, R. J., W. G. Dore, and **J. McNeill.** 1976. [Miscellaneous chromosome counts.] Pages 496–497 *in* A. Löve. Taxon 25: 483–500.

Moore, R. J. 1988. Key to the bedstraws (*Galium*) in Canada. The Plant Press (Mississauga, Ontario) 5(1): 21–23.

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Pierre Fortin (1823–1888) et la première description scientifique du chevalier cuivré, *Moxostoma hubbsi*

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En 1866, le naturaliste canadien Pierre Fortin publie une description très détaillée d'un chevalier (*Moxostoma* sp.) dans la quatrième et dernière section de sa liste des poissons du golfe et du fleuve Saint-Laurent. Nous avons identifié ce spécimen comme étant un chevalier cuivré (*M. hubbsi*). Conséquemment, Pierre Fortin a découvert et décrit cette espèce 76 ans avant Vianney Legendre. Pour parvenir à cette conclusion, nous avons dû préciser l'approche méthodologique de Pierre Fortin en replaçant la description dans son contexte historique. Cette revue de la littérature nous a également permis de documenter l'origine de la nomenclature vernaculaire et l'évolution de la perception de la diversité des catostomidés au Québec. Le chevalier cuivré est endémique au sud-ouest du Québec et actuellement considéré en danger de disparition. Il était une espèce prisée comme aliment et recherchée dans les marchés au dix-neuvième siècle. Il est possible que la surpêche ait fragilisé certaines populations et contribué à leur déclin.

In 1866, Pierre Fortin, a Canadian naturalist, published a detailed description of a redhorse (*Moxostoma* sp.) in the fourth and last section of his list of fishes of the Gulf and River St. Lawrence. We identify this specimen as a Copper Redhorse (*M. hubbsi*). Therefore, Pierre Fortin discovered and described this species 76 years before Vianney Legendre did so. To reach that conclusion, we clarify Fortin's methodology by placing the description in its historical context. This review of the literature also allows us to document the evolution of the perception of catostomid diversity in Quebec and the origin of the French common names to this group of fish. The Copper Redhorse is endemic to southwestern Quebec and currently considered an endangered species. It was prized for food and a popular item on the markets in the nineteenth century. Overfishing may have weakened some populations and contributed to their decline.

Key Words: Copper Redhorse, Chevalier cuivré, *Moxostoma hubbsi*, Pierre Fortin, endemic, Québec.

La documentation historique est un outil précieux en bioconservation pour établir des liens entre les variations d'abondance d'une espèce et les multiples perturbations qui surviennent dans son habitat. Pour ce faire, il est important de caractériser *a priori* l'historique de la perception de l'espèce étudiée jusqu'à sa description et sa reconnaissance scientifique définitive. Un des objectifs de cet article est de retracer l'évolution de la perception des différentes espèces de poissons de la famille des catostomidés au Québec et plus particulièrement celle du chevalier cuivré (*Moxostoma hubbsi*), une espèce endémique à la région de Montréal et actuellement en danger de disparition (Mongeau et al. 1988; Comité d'intervention 1995).

La présence de plusieurs espèces de catostomidés dans les eaux douces du Québec a attiré l'attention des explorateurs et naturalistes dès le début de la colonisation. Samuel de Champlain (1567–1635) parlant de la "pesche du poisson" mentionne qu'il y a dans le fleuve Saint-Laurent des "carpes de toutes sortes, dont y en a de tres-grandes" (Champlain 1598–1632). Il ne s'agit en aucun cas de la vraie carpe (*Cyprinus carpio*) qui ne gagne le fleuve Saint-Laurent que vers 1910 (MacCrimmon 1972). Dans son *Histoire véritable et naturelle de la Nouvelle-France*, Pierre Boucher (1622–1717) distingue également plusieurs espèces de catostomidés : "Les poissons qui se trouvent dans les petits lacs & les petites rivières, sont brochets, carpes de plusieurs sortes; perches, braimes, petites truites, poissons dorez, ouchigans..." (Boucher 1664). Malgré cet éveil hâtif, il faudra attendre 1952 avant que ne soit clarifiée définitivement la taxinomie des huit espèces de catostomidés présentes sur le territoire du Québec avec la désignation du chevalier cuivré comme espèce nouvelle (Legendre 1952).

Entre Boucher (1664) et Legendre (1952), la liste des poissons du Saint-Laurent publiée par Pierre Fortin dans les années 1860 marque une avancée importante et le début de l'ichtyologie régionale au Québec (Fortin 1863a, b; 1864a, b; 1865a, b; 1866a, b). Cette liste n'est pas une simple compilation bibliographique. La grande valeur des travaux de Pierre Fortin vient du fait que les espèces listées proviennent de spécimens capturés localement et que la majorité des descriptions résultent d'observations et de mesures qu'il a lui-même effectuées d'après nature (Préfontaine 1946; Potvin 1952). Bien que généralement associée au milieu marin du golfe Saint-Laurent, cette liste présente 37 espèces de poissons fréquentant les eaux douces du fleuve, contre 30 espèces strictement marines. Si les premières descriptions qu'il fait sont non spécifiques ou incomplètes, elles atteignent, dans les rapports de 1865 et 1866, un niveau de précision scientifique qui permet de comparer Pierre Fortin aux autres ichtyologistes mieux connus de son époque. Pour la famille des catostomidés, il décrit quatre espèces dont une "très grande", le catostome aux grandes écailles (Fortin 1866a, b). La description du catostome aux grandes écailles est suffisamment détaillée pour penser qu'il s'agit en réalité du chevalier cuivré. Afin de vérifier cette hypothèse, nous replaçons la description de Pierre Fortin dans le contexte ichtyologique de l'époque. Nous identifions les principaux documents qu'il a consultés pour la préparation de sa liste et plus particulièrement pour la description des différentes espèces de catostomidés. Enfin, nous comparons les mesures morphologiques présentées par Pierre Fortin avec des données recueillies sur des spécimens actuels dûment identifiés.

Méthodologie

Caractérisation de l'univers ichtyologique de Pierre Fortin

L'absence d'une section bibliographique rend difficile l'identification des documents dont disposait Pierre Fortin au moment d'écrire sa liste des poissons du Saint-Laurent. Il mentionne toutefois le nom, sans date, de quelques auteurs dans les rapports de 1864, 1865 et 1866. Pour déterminer les documents qu'il a consultés, nous avons dressé, dans un premier temps, la liste des noms d'auteurs cités et avons relevé dans le texte tous les commentaires se rapportant à un auteur ou à un document particulier. Les auteurs anciens, comme Linné, qui n'apparaissent qu'en compagnie d'un nom scientifique et dont l'origine peut être facilement retracée à partir des documents plus récents, ont été exclus. Nous avons ensuite comparé la nomenclature utilisée par Pierre Fortin et ses descriptions avec celles des ouvrages des auteurs retenus pour établir une liste de références finale.

Afin de caractériser le contexte ichtyologique local de l'époque, nous avons consulté les documents de nature scientifique ayant un lien avec les poissons du Bas-Canada et publiés peu avant 1867. Ils ont été retracés à partir des inventaires de Dionne (1905, 1906) et des listes de références de Dymond (1964), Scott et Crossman (1974) et Legendre et al. (1980). Nous avons porté une attention particulière aux travaux publiés dans le *Canadian Naturalist and Geologist* et le *Transactions of the Literary and Historical Society of Quebec* deux importants véhicules locaux de communication scientifique à cette époque.

Une fois ces informations en main, il a été possible de préciser davantage l'approche méthodologique (définition des termes utilisés, provenance des spécimens, etc) suivie par Pierre Fortin pour ses descriptions.

Identification du catostome aux grandes écailles

En plus de décrire plusieurs traits morphologiques qui limitent à deux espèces l'identité possible du catostome aux grandes écailles, Pierre Fortin présente 27 mesures morphométriques et 8 mesures méristiques. Les caractères communs à l'ensemble du genre *Moxostoma*, donc peu utiles pour identifier à l'espèce, ont été exclus. La longueur de la tête (de l'extrémité antérieure du museau à la marge postérieure osseuse de l'opercule), la largeur maximale de la tête (à l'extrémité postérieure de la tête) et la hauteur maximale du corps (à l'origine de la nageoire dorsale) ont été retenues pour comparer le catostome aux grandes écailles avec le chevalier cuivré et le chevalier de rivière (*Moxostoma carinatum*). Ces caractères ont été comparés en valeur relative de la longueur totale (de l'extrémité antérieure du museau à la marge postérieure de la nageoire caudale). La banque de données initiale comprend des mesures effectuées sur 119 chevaliers cuivrés et 1062 chevaliers de rivière. Nous avons exclu les spécimens de taille inférieure à 500 mm afin de tenir compte des variations morphométriques dues à la taille (le catostome aux grandes écailles de Fortin mesure 673 mm). Pour des raisons similaires, nous n'avons retenu que les chevaliers de rivière originaires du Québec. Cette sélection a permis de comparer le catostome aux grandes écailles avec 11 chevaliers cuivrés et 9 chevaliers de rivière.

Résultats

La documentation

Les livres utilisés par Pierre Fortin comme support à la rédaction de sa liste des poissons du golfe et du fleuve Saint-Laurent sont présentés au Tableau 1. Tous ces documents ont plus de dix ans au moment où Fortin écrit sa liste. Il ne cite pas les derniers ouvrages disponibles à l'époque comme ceux de Günther ou d'Agassiz, ce qui suggère que ses contacts scientifiques extérieurs à la province du Canada sont restreints. Des livres consultés par Pierre Fortin, seuls ceux de Cuvier et Valenciennes (1844), De Kay (1842), Storer (1839) et Richardson (1836) présentent une section importante sur les catostomidés. De plus, il est possible que Pierre Fortin ait pris connaissance de certains des travaux de Charles-Alexandre Le Sueur (1778–1846) publiés dans différents périodiques, dont un article du *Journal of the Academy of Natural Sciences of Philadelphia* portant sur les catostomidés (Le Sueur 1817).

Fortin cite également Bloch, Forster, Lacépède, Linné et Pallas. Le nom de ces auteurs suit généralement un nom scientifique et rien dans le corps du texte n'indique qu'il avait les documents originaux sous les yeux. Il est possible de retracer tous ces auteurs et le nom scientifique qu'ils accompagnent dans l'un ou l'autre des sept ouvrages du Tableau 1. L'appellation erronée de "Mitchell" (Fortin 1865b,

TABLEAU 1. Reconstitution de la liste des ouvrages d'ichtyologie consultés par Pierre Fortin.

Auteur	Titre	Année
Cuvier	The class Pisces by the Baron Cuvier with supplementary additions, by Edward Griffith and Charles Hamilton Smith	1834[a]
Cuvier et Valenciennes	Histoire naturelle des poissons (22 tomes)	1828–1849
De Kay	Zoology of New-York, or the New-York Fauna. Part IV. Fishes	1842
Herbert	Frank Forester's fish and fishing of the United States and British Provinces of North America	1850[b]
Richardson	Fauna Boreali-Americana; or the zoology of the northern parts of British Americana: part third. The fish	1836
Storer[c]	Report on the ichthyology and herpetology of Massachusetts	1839
Yarrell	A history of British fishes (2 tomes)	1836 ou 1841[d]

[a]*Le Règne animal* de Cuvier a été publié de 1815 à 1817.
[b]Cet ouvrage est paru pour la première fois en 1849.
[c]Cet auteur a également écrit *A synopsis of the fishes of North America* paru en 1846.
[d]En plus de la première (1836) et de la deuxième édition (1841), il y en a eu une troisième en 1859 réalisée avec la collaboration de J. Richardson.

pages 68 et 72), au lieu de Mitchill, laisse croire qu'il reproduit l'erreur commise par Storer (1839) et qu'il n'a pas consulté *Fishes of New-York* publié en 1815. L'allusion aux travaux de Smith (Fortin 1865b, page 66) se rapporte à Charles Hamilton Smith, collaborateur à la traduction anglaise du *Règne Animal de Cuvier* (1834).

Potvin (1952) indique que Pierre Fortin avait monté une bibliothèque, dans le carré de la "Canadienne" (la goélette sur laquelle il passait la moitié de l'année), composée principalement d'ouvrages d'auteurs canadiens et de livres d'histoire naturelle. Ainsi, Pierre Fortin avait plusieurs autres documents moins spécialisés à sa disposition comme en témoignent ses allusions aux écrits d'Aristote, Juvénal, Martial et Sénèque dans sa liste des poissons.

La nomenclature

Les noms scientifiques des cinq descriptions de catostomidés produites par Fortin proviennent tous du dix–septième tome de l'*Histoire naturelle des poissons* de Cuvier et Valenciennes (1844) (Tableau 2). Les noms techniques émanent également de Cuvier et Valenciennes (1844), alors que les noms vernaculaires anglais sont tirés de De Kay (1842). La nomenclature utilisée nous laisse croire que ces deux ouvrages ont constitué l'essentiel du support bibliographique de Fortin pour la comparaison des différentes espèces de catostomidés.

En plus des noms français techniques, Fortin présente plusieurs noms vernaculaires dont certains apparaissent pour la première fois dans la littérature (Tableau 2). Outre les noms d'en-tête rapportés au Tableau 2, on retrouve dans le corps du texte

TABLEAU 2. Nomenclature utilisée par Pierre Fortin dans les en-têtes de présentation de ses cinq descriptions de catostomidés.

		Noms vernaculaires	
Noms scientiques	Noms techniques	anglais	français
	Rapport de 1864		
Catostomus communis	Catostome	Common Sucker	Carpe
	Rapport de 1866		
Catostomus forsterianus (Cuvier et Valenciennes)[a]	Catostome de Forster	Red Sucker	Carpe de rapides Meunier
Catostomus tuberculatus (Le Sueur)	Catostome tubercule (Cuvier et Valenciennes)	Horned Sucker	Carpe au nez galeux
Catostomus macrolepidotus (Le Sueur)[b]	Catostome aux grandes écailles (Cuvier et Valenciennes)	Large scaled Sucker	Carpe blanche
Sclerognathus cyprinus (Le Sueur)	Sclerognathe cyprin (Cuvier et Valenciennes)	Long-finned Chub Sucker	Brême Brume

[a]Il utilise également le nom scientifique donné par Forster (1773) dans la description originale de l'espèce (*Cyprinus catostomus*).
[b]Il est écrit *Catostamus* au lieu de *Catostomus* dans l'en-tête de la version française du rapport de 1866.

quelques références intéressantes d'un point de vue terminologique. A propos des catostomidés, il écrit : "On en compte un grand nombre de variétés; celles appelées carpes de France et carpes au nez galeux sont excellentes" (Fortin 1864b); des termes traduits par "french carps" et "scabby snout suckers" dans la version anglaise (Fortin 1864a). Il fait clairement la distinction entre les catostomidés indigènes et la "vraie carpe" introduite "il y a une trentaine d'années... dans quelques lacs de l'Etat de New-York", mais absentes au Québec comme en témoigne le passage suivant : "mais je ne sache pas qu'on en ait encore vu dans notre pays" (Fortin 1864b). Il écrit même à propos du catostome qu'il est "improprement appelé en Canada Carpe" (Fortin 1864b). Ailleurs, il dit avoir trouvé un "petit catostome (carpe) de $4^1/_2$ pouces de longueur" dans le contenu stomacal d'un poulamon atlantique (*Microgadus tomcod*) (Fortin 1864b).

Le contexte ichtyologique local

Le Bas-Canada vit une certaine effervescence ichtyologique dans les années 1850 et 1860, à l'époque même où Pierre Fortin écrit sa liste des poissons du golfe et du fleuve Saint-Laurent. Les articles parus dans le *Canadian Naturalist and Geologist*, dès sa fondation en 1856, sont particulièrement riches d'informations. Nous avons trouvé quelques extraits qui ne sont pas sans intérêt pour décrire le climat ichtyologique local de l'époque. Forelle (1856) écrit ceci d'intéressant sur la diversité des catostomidés: "In Cyprinidae, the Carp family, we have several species of the genus *Catastomus* and of the genus *Leuciscus*. The common sucker, *Catastomus communis*, and the Mullet Sucker, *Catastomus aureolus*, are perhaps the most common species of the genus. Here also there is opportunity for careful examination by the Canadian student, as accurate descriptions of the different species are very much needed". Forelle ne fait pas de distinction entre les catostomidés et les cyprinidés pas plus qu'il ne distingue le genre *Catostomus* du genre *Moxostoma*. Toutefois, ce qu'il faut souligner de ce passage, c'est cet appel à la description méticuleuse des différentes espèces de catostomes afin dit-il, "de mettre de l'ordre dans la confusion actuelle". Toujours dans le même périodique, D'Urban (1859) dénonce l'absence d'une collection de référence pour comparer les spécimens qu'il capture. La préservation dans l'éthanol est une technique connue par celui-ci qui se plaint des difficultés que comporte le transport des spécimens préservés entre les sites d'échantillonnage. Il mentionne la présence de deux espèces de "*Catastomus*" dans le bassin de drainage de la rivière Rouge dans la région "D'Argenteuil et d'Ottawa".

Les pêcheries du golfe Saint-Laurent font l'objet de nombreux articles comme ceux de Gill (1865) et d'Austin (1866) dans lesquels les rapports de Pierre Fortin sont cités. Dans son synopsis des poissons du golfe Saint-Laurent, Gill (1865) rapporte aussi plusieurs espèces des eaux intérieures de la région de la baie de Fundy, dont deux espèces de catostomidés.

La publication de livres n'échappe pas à l'engouement ichtyologique de l'époque. En 1857, Nettle publie *Salmon fisheries of the St. Lawrence* alors qu'en 1863 LeMoine livre au peuple *Les pêcheries du Canada*; deux ouvrages sans référence aux catostomidés. L'excellent livre de H. Beaumont Small daté de 1865 (la préface est signée à Montréal le premier août 1866) mérite qu'on s'y attarde quelque peu pour bien dépeindre le climat de l'époque. Dans la préface, il appelle le lecteur à l'indulgence et justifie les inexactitudes en ces termes "...the difficulty of obtaining fresh specimens, as well as from the inutility of dried or preserved specimens as a reference, and the scarcity of any reliable works on this branch of Natural History...". Le livre présente 74 espèces de poissons d'eau douce, dont huit espèces de "*Catastomus*". La section sur les catostomidés est principalement inspiré de De Kay (1842). A propos des espèces de ce genre, Small écrit ceci : "Very little attention has been paid to the careful discrimination of species in this genus; a better defined character of it, and a careful comparison and description of the species is still a desideratum". Les huit descriptions ne sont pas discriminantes, mais ses différentes remarques laissent penser qu'il distinguait cinq espèces de catostomidés dans la région de Montréal.

Certains naturalistes du Bas-Canada collaborent avec des musées situés outre-mer et aux États-Unis. Dans son catalogue des poissons de la collection du "British Museum", Günther (1868) liste sous le nom de *Catostomus carpio* cinq spécimens achetés à Montréal par un dénommé Monsieur Wright. Il était pratique courante à l'époque de se procurer des spécimens dans les marchés afin d'étudier la faune locale (Gaboriault 1974). Nous avons pu examiner et ré-identifier ces spécimens à la suite d'un emprunt au British Museum. Le numéro de collection des spécimens indique qu'ils ont été capturés en 1866. Il s'agit de quatre chevaliers blancs (*Moxostoma anisurum*) et d'un chevalier rouge (*Moxostoma macrolepidotum*). Le même personnage a également fourni six meuniers noirs (*Catostomus commersoni*) au British Museum classés sous le nom de *Catostomus teres*. Le nombre d'écailles le long de la ligne latérale de ces individus (60–65), tel que rapporté par Günther (1868), est caractéristique de cette espèce. Meuniers et chevaliers sont donc au menu des marchés de Montréal dans les années 1860. En 1869, Whiteaves publie une note annonçant la sortie de ce septième volume du catalogue de Günther. Outre ces deux espèces de catostomidés de la région de Montréal présentées par Günther, Whiteaves (1869) spécifie que l'on peut aussi y retrouver le "*Catastomus hud-*

sonius" et le "*Carpiodes cyprinus*". Il s'agit selon toute vraisemblance du meunier rouge (*Catostomus catostomus*) et de la couette (*Carpiodes cyprinus*), deux espèces qui font également l'objet d'une description de la part de Günther (1868).

Fortin ne mentionne aucun de ces travaux. L'isolement des longs voyages sur le golfe Saint-Laurent l'empêchait peut-être d'entretenir une relation étroite avec l'intelligentsia du Bas-Canada. A l'inverse, les travaux de Pierre Fortin étaient bien connus à l'époque. Publiés d'abord comme document de la session de l'Assemblée législative de la province du Canada, ses rapports étaient également distribués, pour une meilleure diffusion, en français et en anglais sous forme de tirés-à-part.

L'approche méthodologique

Les descriptions de Pierre Fortin sont généralement faites d'après nature et à l'endroit même où il pratiquait l'examen des sujets étudiés (Préfontaine 1946; Potvin 1952). Dans l'ensemble, les descriptions donnent l'impression d'une approche méthodologique honnête comme le suggère son commentaire sur le décompte des rayons d'un petit spécimen de *Liparis* : "Quant aux pectorales et aux ventrales, n'ayant pas de loupe avec moi, il m'a été impossible de les compter" (Fortin 1864b), où plutôt que de donner une approximation, il s'est abstenu. Pierre Fortin avait d'ailleurs une formation scientifique ayant obtenu un diplôme en médecine de l'Université McGill en 1845 (Stewart 1997).

Le poste de protecteur des pêcheries plaçait Pierre Fortin dans une position favorable par rapport à ses contemporains pour pouvoir se procurer des spécimens frais. Il mentionne plusieurs collaborateurs dans ses rapports, des pêcheurs commerciaux pour la plupart, mais également des autochtones et des membres de son équipage. Certaines descriptions proviennent de spécimens retrouvés morts sur le rivage. Sa curiosité l'amenait parfois à chercher sur les berges à marée basse les petits poissons cachés sous les algues (Fortin 1864b). Il mentionne s'être procuré lui-même certaines espèces au moyen de techniques de pêche variées, la seine et l'épuisette notamment. Certains de ses spécimens pouvaient également provenir des marchés locaux, comme ce "crapais" qu'il dit s'être procuré à Montréal (Fortin 1865b).

La précision des mesures morphométriques effectuées par Pierre Fortin est généralement de ± 6,4 mm (quart de pouce); dans le cas des petites structures comme les écailles, elle est de ± 3,2 mm (huitième de pouce). Dans la description du catostome aux grandes écailles, Fortin (1866b) utilise les termes suivants : "longueur totale", "longueur de la tête", "épaisseur en arrière de la tête" et "largeur en avant de la nageoire dorsale", pour désigner les quatre mesures morphométriques que nous utilisons pour la comparaison avec les chevaliers cuivré et de rivière.

Parmi les ouvrages de référence à la disposition de Pierre Fortin (Tableau 1), ceux de Cuvier et Valenciennes (1828), Richardson (1836) et Yarrell (1841) renferment plusieurs détails techniques de description morphologique, particulièrement dans leur partie respective sur la perche (*Perca* sp.), qui permettent de préciser la signification de certains termes employés à l'époque. La longueur totale d'un poisson est la longueur depuis la fin du museau jusqu'à la pointe de la nageoire caudale (Richardson 1836). La longueur de la tête est définie comme la longueur depuis le museau jusqu'à la marge postérieure de l'opercule (Cuvier et Valenciennes 1828; Richardson 1836). Jusqu'ici, il y a concordance parfaite entre les définitions des mesures morphométriques présentées dans la section méthodologie et celles de l'époque. Pierre Fortin laisse voir une certaine méconnaissance de la terminologie ichtyologique en employant le terme "épaisseur" pour "largeur" et "largeur" pour "hauteur". Cette déviation terminologique pourrait s'expliquer par la position généralement couchée d'un spécimen durant son examen. Dans la description du crapet-soleil (*Lepomis gibbosus*), une espèce comprimée latéralement, il donne les dimensions suivantes : 165 mm en longueur, 98 mm en largeur et 29 mm en épaisseur (Fortin 1865b). Cet exemple confirme notre interprétation des mots épaisseur et largeur. Il est donc fondé de faire correspondre épaisseur en arrière de la tête avec largeur maximale de la tête ainsi que largeur en avant de la nageoire dorsale avec hauteur maximale du corps.

Un des éléments clefs de l'identification du catostome aux grandes écailles est la signification du terme "protubérances osseuses". Pierre Fortin (1866b) écrit qu'il y a plusieurs protubérances osseuses à la partie antérieure de la tête du spécimen. Il ne pourrait s'agir d'une autre structure anatomique que les tubercules nuptiaux qui apparaissent progressivement dès l'automne chez certaines espèces de catostomidés et qui disparaissent après la fraie. Chez ces espèces, les tubercules nuptiaux de la tête sont blancs et ont la consistance du tissu osseux. Cette interprétation paraît quelque peu problématique parce que Fortin utilise justement le mot tubercule pour désigner les tubercules nuptiaux de la nageoire anale et caudale du meunier rouge (Fortin 1866b). Un tel changement de terminologie n'est toutefois pas exceptionnel dans les descriptions de Pierre Fortin. Le terme tubercule est d'ailleurs utilisé à toutes les sauces, que ce soit pour décrire la peau de la grosse poule de mer (*Cyclopterus lumpus*) ou la surface des caroncules de la bouche du meunier rouge (Fortin 1864b; Fortin 1866b). Dans la description du catostome aux grandes écailles, il utilise également le mot tubercule, mais cette fois pour désigner les pores des canaux de la ligne latérale qui parcourent la tête (Fortin 1866b). Pour d'autres espèces, il désigne ces mêmes organes par "pores muqueux" ou simplement par "petits trous" (Fortin 1866b).

Pierre Fortin a contribué à enrichir la collection du Musée zoologique de l'Université Laval avec de nombreux spécimens d'oiseaux et de poissons (Potvin 1952; Gaboriault 1974). Il indique dans une lettre adressée au recteur de cette université qu'il avait un "empailleur" à son emploi (Fortin 1873*). L'origine exacte des six catostomidés naturalisés qui sont conservés dans cette collection, maintenant localisée au Musée de l'Amérique française à Québec, n'est pas connue. Nous y avons identifié trois meuniers noirs, un meunier rouge, un chevalier rouge et une couette. A cause de sa taille (546 mm), le seul chevalier de cette collection ne pourrait être le catostome aux grandes écailles (673 mm) décrit par Pierre Fortin.

Identification du catostome aux grandes écailles

Fortin n'indique pas la provenance exacte du spécimen, mais il mentionne ceci : "Je me suis procuré plusieurs spécimens du catostome aux grandes écailles, car ce poisson est assez commun dans le fleuve St. Laurent et dans nos rivières. On en prend beaucoup au printemps près de Sorel et dans le lac St. Pierre. Il est assez recherché sur nos marchés, car sa chair est agréable au goût" (Fortin 1866b). Il est vraisemblable que le spécimen provient d'un pêcheur commercial du fleuve Saint-Laurent, quelque part entre le lac Saint-Louis et le lac Saint-Pierre. Fait à noter, le poisson-castor (*Amia calva*), qu'il décrit la même année, a été pris dans le fleuve Saint-Laurent aux environs de Sorel.

La date de capture du catostome aux grandes écailles n'est pas mentionnée. Il a probablement été capturé entre novembre et le début de mai, soit entre deux missions de surveillance dans les eaux du golfe Saint-Laurent. Les descriptions du meunier rouge et de la couette, publiées la même année, proviennent de spécimens capturés à la seine dans le fleuve Saint-Laurent à Laprairie au printemps de 1865 et plus précisément le 25 avril dans le cas du meunier rouge (Fortin 1866b). Ces informations et la présence des nombreux tubercules nuptiaux suggèrent que le spécimen a été capturé au printemps de 1865.

Fortin (1866b) classe le catostome aux grandes écailles dans l'ordre des "malacoptérygiens abdominaux", dans la famille des "cyprinoïdes" et dans le genre "catostome". La description générale correspond à un catostomidé type. La présence d'une "vessie natatoire,..., divisée en trois lobes" écarte d'ailleurs tout poisson autre qu'un spécimen de l'une ou l'autre des cinq espèces du genre *Moxostoma* retrouvées dans le fleuve Saint-Laurent. Il commente ainsi la taille de son spécimen : "Parmi les nombreuses variétés du genre catostome qui habitent les eaux douces de l'Amérique du Nord, peu d'entre elles, je crois, atteignent une taille plus grande que celle qui fait le sujet de cette courte description". Bien que la longueur totale du spécimen (673 mm) soit davantage caractéristique du chevalier cuivré, elle n'exclut pas pour autant le chevalier de rivière et le chevalier jaune (*Moxostoma valenciennesi*).

L'individu possède "plusieurs protubérances osseuses à la partie antérieure" de la tête. Il s'agit donc des tubercules nuptiaux que l'on retrouve sur la tête des mâles du chevalier cuivré et du chevalier de rivière (rarement sur les femelles). Ce caractère exclut d'emblée le chevalier rouge, le chevalier blanc et le chevalier jaune. Chez les chevaliers rouge et jaune, les tubercules nuptiaux sur la tête des mâles sont minuscules et difficilement détectables; ils ne sauraient être qualifiés de "protubérances osseuses".

L'ensemble de ces informations limitent donc à deux espèces les possibilités d'identification du catostome aux grandes écailles, soit le chevalier cuivré et le chevalier de rivière. La comparaison des caractères morphométriques indique que le spécimen décrit sous le nom de catostome aux grandes écailles (*Catostomus macrolepidotus*) est un chevalier cuivré (*Moxostoma hubbsi*) (Tableau 3). La longueur et la largeur de la tête du catostome aux grandes écailles sont diagnostiques et ne chevauchent pas l'étendue des valeurs observées chez le chevalier de rivière. La petitesse de la tête ne pourrait d'ailleurs correspondre qu'à un chevalier cuivré ou à un chevalier rouge. Quant à la hauteur du corps, elle est caractéristique d'un chevalier cuivré même si elle chevauche quelque peu l'étendue des valeurs observées pour le chevalier de rivière (Tableau 3).

Certains traits qualitatifs fournis dans la description sont typiques du chevalier cuivré. Par exemple, Fortin décrit ainsi la forme particulière de la tête et du dos : "Tête plus longue que large, sans écailles, avec plusieurs protubérances osseuses à la partie antérieure; *arquée ainsi que le dos jusqu'à la dorsale*". Dans cet extrait, la disposition des nombreux tubercules nuptiaux à la partie antérieure de la tête correspond davantage au chevalier cuivré qu'au chevalier de rivière chez qui, ils sont peu nombreux et concentrés sur le museau. Pierre Fortin indique avoir quatre spécimens à sa disposition, mais il est impossible de vérifier s'ils étaient tous des chevaliers cuivrés.

Evermann et Kendall (1902) sont les seuls, à notre connaissance, qui ont interprété la description du catostome aux grandes écailles de Pierre Fortin dans leur liste des poissons du fleuve Saint-Laurent. Ils en font un synonyme de chevalier rouge. Cette interprétation est toutefois prudente et accompagnée d'un point d'interrogation. Ce rarissime bémol de la liste indique bien que la description du catostome aux grandes écailles ne trouvait pas d'équivalence dans la littérature scientifique de l'époque ou dans les collections de référence des deux auteurs.

TABLEAU 3. Comparaison morphométrique du catostome aux grandes écailles avec le chevalier cuivré et le chevalier de rivière. Les résultats sont exprimés en valeur relative de la longueur totale.

Caractère	chevalier cuivré (moyenne et étendue, n = 11)	catostome aux grandes écailles	chevalier de rivière (moyenne et étendue, n = 9)
Longueur de la tête	17,8 17,0–18,5	17,0 ↲	19,5 18,1–20,7
Largeur de la tête	14,1 13,6–15,4	14,2 ⇦	12,9 11,8–14,0
Hauteur du corps	23,7 21,3–25,5	22,6 ⇦	21,2 19,1–22,7

Les autres catostomidés décrits par Pierre Fortin

La description du "*Catostomus communis*", présentée dans le rapport de 1864, est très générale. Elle s'applique parfois au meunier rouge, au meunier noir et en d'autres passages, à la famille des catostomidés. Il ne faut pas s'étonner que le "*Catostomus communis*" de Fortin ait été interprété comme un meunier rouge dans certaines publications (Evermann et Goldsborough 1907; Scott et Crossman 1974) et comme un meunier noir dans d'autres (Evermann et Kendall 1902; Richardson 1935). La présence de l'espèce dans les rivières Saint-Augustin et "Pacachoo" (rivière Pagachou) situées en Basse-Côte-Nord laisse toutefois penser qu'il était davantage en contact avec le meunier rouge que le meunier noir, une espèce absente dans cette région. Pierre Fortin revient avec une excellente description du meunier rouge dans son rapport de 1866. Les 95 écailles le long de la ligne latérale du spécimen ne laissent aucun doute sur l'identité du "*Catostomus forsterianus*" (Fortin 1866b). Il y a d'ailleurs unanimité quant à son identification (Evermann et Kendall 1902; Evermann et Goldsborough 1907; Richardson 1935; Scott et Crossman 1974).

La description du "*Catostomus tuberculatus*" publiée en 1866 est sommaire mais contrairement à celle du "*Catostomus communis*" de 1864, elle repose sur un véritable spécimen (Fortin 1866ab). Les écailles "grandes et striées" du sujet étudié pourraient convenir au meunier noir ou à l'une ou l'autre des cinq espèces de chevaliers du fleuve Saint-Laurent, les 15 rayons de la nageoire dorsale excluant la couette. Toutefois, Pierre Fortin mentionne, dans la version anglaise du rapport de 1866, qu'il y a 11 écailles de la partie antérieure de la base de la nageoire dorsale jusqu'à la ligne latérale (Fortin 1866a), une caractéristique propre au meunier noir. Avec les 16 écailles de la ligne latérale à la partie médiane de l'abdomen (Fortin 1866a), on obtient environ 54 écailles autour du corps, un autre trait diagnostique de cette espèce. Pierre Fortin indique qu'il y a "quatre tubercules sur le museau". Encore une fois, le mot tubercule prend une autre signification. Chez le meunier noir, il y a un épaississement de la peau de la tête avant la période de fraie. Ce phénomène prend parfois l'apparence de plaques blanchâtres sur le museau. Voilà ce qui pourrait expliquer le nom vernaculaire de "carpe au nez galeux". A propos du meunier noir, Fortin (1866b) écrit ceci : "Cette variété du genre catostome est une des meilleures que nous ayons pour la table. Elle est agréable au goût et saine. On n'y retrouve pas non plus autant de petites arêtes que dans la plupart des autres catostomes".

La dernière espèce de catostomidés décrite par Fortin (1866b) est le "*Sclerognathus cyprinus*". Il s'agit d'une description rigoureuse qui conduit sans difficulté à identifier le spécimen comme étant une couette avec ses 40 écailles à la ligne latérale et sa nageoire dorsale composée de 31 rayons, dont "les troisième, quatrième et cinquième" sont très longs. Evermann et Kendall (1902) arrivent également à cette conclusion. A propos de sa consommation, Fortin (1866b) y va du commentaire suivant : "Ce poisson est excellent à manger et d'une chair ferme".

Discussion

La description du chevalier cuivré de Pierre Fortin ne change rien à la nomenclature actuelle puisque celui-ci n'a pas utilisé un nom nouveau. En effet, *macrolepidotus* est le nom donné par Le Sueur au chevalier rouge en 1817 et repris ensuite dans Cuvier et Valenciennes (1844). Pierre Fortin cherchait avant tout à identifier ses spécimens et sous-estimait l'originalité de son travail. S'il avait su, Vianney Legendre aurait sans doute rendu hommage à Pierre Fortin en utilisant son patronyme comme nom scientifique de l'espèce.

A la description du chevalier cuivré de Pierre Fortin, il ne manque que les arcs pharyngiens, si caractéristiques de l'espèce avec leurs grosses dents molariformes. Le chevalier cuivré utilise ces dents pour broyer la coquille des mollusques qui composent la presque totalité de son régime alimentaire (Mongeau et al. 1986). Fortin (1866b) connaissait pourtant les dents pharyngiennes des "cyprinoïdes" car il les décrit pour quelques espèces de ménés. Dans le dix-septième tome de l'*Histoire naturelle des* *poissons*, Achille Valenciennes ridiculise l'utilisation des dents pharyngiennes dans la systématique des cyprins et des catostomes (Cuvier et Valenciennes 1844). Voilà ce qui pourrait expliquer le mutisme de Pierre Fortin et révéler une certaine prudence dans ses descriptions. Comme nous l'avons déjà indiqué, les ouvrages de Cuvier et Valenciennes (1844) et de De Kay (1842) ont été de précieux guides pour la rédaction de la section sur les catostomidés.

Il est également possible que Pierre Fortin ait omis volontairement plusieurs détails dans ses descriptions parce que ceux-ci étaient discordants avec la littérature. Dans le cas du meunier noir, il ne mentionne pas, contrairement aux trois autres espèces de catostomidés décrites dans le rapport de 1866, le décompte des écailles le long de la ligne latérale. La description du *Catostomus tuberculatus* de Cuvier et Valenciennes (1844) indique seulement "quarante rangées d'écailles sur le côté" alors que son spécimen de meunier noir devait en avoir plus de 50. Dans cette même description, Valenciennes écrit à propos des tubercules nuptiaux: "...il y a lieu de croire que les tubercules ne sont pas aussi caractéristiques que l'a pensé M. Le Sueur. Il est très-probable qu'ils sont caduques, et qu'ils se développent peut-être pendant certaines saisons sur le museau de l'animal...". Voilà ce qui pourrait expliquer en partie pourquoi Pierre Fortin n'a pas compris qu'il était en présence d'une nouvelle espèce jusque là non décrite, le chevalier cuivré.

Le chevalier cuivré au dix-neuvième siècle

Au fur et à mesure que progresse sa liste des poissons du golfe et du fleuve Saint-Laurent, Pierre Fortin concentre sa recherche de spécimens dans la région de Montréal et décrit plusieurs espèces que l'on retrouve surtout dans le sud-ouest du Québec. Il n'est donc pas étonnant qu'il ait rencontré le chevalier cuivré sur son passage. La présence des gros chevaliers dans les rapides aux alentours de Montréal en juin et juillet, soit durant leur période de fraie, était bien connue à l'époque (Small 1865; Montpetit 1872). Même si elle ne permet pas d'identifier à l'espèce, la description du "rock sucker *Catastomus Sueuri*" de Small (1865) est particulièrement révélatrice à ce sujet : "Brilliant metallic colours, scales very large, air bladder divided into three portions. This species... is, according to our opinion, the sucker which is taken among rocks in the shallows of the St. Lawrence near Montreal, in June and July, succeeding the common sucker, from which it differs in having its flesh firmer and being more free from small bones. It sometimes attains nineteen inches in length, and weighs from four to eight pounds." Cette connaissance qu'on avait des chevaliers était sûrement entretenue par leur exploitation commerciale. La consommation humaine et le commerce des catostomidés au dix-neuvième siècle ont été soulignés à plusieurs reprises dans la littérature (Le Sueur 1817; Richardson 1836; Cuvier et Valenciennes 1844; Fortin 1864b, 1866b; Small 1865; Günther 1868; Cope 1870; Montpetit 1872, 1897; Provancher 1875). Des fouilles archéologiques révèlent même que les catostomidés étaient servis dans les auberges de Montréal à cette époque (Ostéothèque de Montréal 1984). Au Québec, la présence des catostomidés dans les marchés remonte aussi loin qu'au début du dix-huitième siècle (Le Beau 1738).

La découverte de la description du chevalier cuivré de Pierre Fortin ne nous renseigne pas directement sur l'état des populations dans les années 1860. Le commentaire de Fortin (1866b) sur l'abondance de l'espèce ("...ce poisson est assez commun dans le fleuve St. Laurent et dans nos rivières.") s'applique probablement aux gros chevaliers d'une façon non spécifique. On peut toutefois s'interroger sur le fait que Pierre Fortin ait décrit le chevalier cuivré plutôt que les chevaliers rouge et blanc, deux espèces nettement plus abondantes. Cette situation pourrait s'expliquer par une pêche commerciale dirigée vers les gros *Moxostoma*, nonobstant l'espèce. Rappelons que le chevalier cuivré décrit par Pierre Fortin origine probablement d'une pêcherie commerciale. La proportion élevée de chevaliers cuivrés et de rivière dans les fouilles archéologiques (Ostéothèque de Montréal 1984; Mongeau et al. 1986) vient également appuyer cette hypothèse d'une pêche sélective. Les pêcheurs commerciaux de l'époque devaient répondre à une certaine demande des marchés publics d'alimentation pour les gros *Moxostoma*. A propos du chevalier cuivré, Fortin (1866b) écrit d'ailleurs: "Il est assez recherché sur nos marchés, car sa chair est agréable au goût".

Il est possible que les pêcheries commerciales aient fragilisé certaines populations de chevalier cuivré au cours du dix-neuvième siècle et dans la première moitié du vingtième siècle. Aux États-Unis, Cope (1870) note la destruction massive, en période de fraie, de plusieurs populations de chevaliers et invite les autorités de la Caroline du Nord à légiférer pour sauvegarder cette importante ressource. Nash (1908) indique que la pêche intensive sur les frayères serait responsable de la situation précaire des chevaliers dans la section ontarienne du fleuve Saint-Laurent et des grands lacs; il fait probablement allusion au chevalier jaune (Scott et Crossman 1974). Pareilles pêcheries sur les frayères existaient également au Québec durant le dix-neuvième siècle (Montpetit 1872; Provancher 1875). La pêche commerciale des chevaliers était encore importante dans les années 1940 dans le fleuve Saint-Laurent (Vladykov 1942a, Cuerrier 1962). Au lac Saint-Pierre, les chevaliers arrivaient seconds dans les débarquements, devancés seulement par la barbotte brune (*Ameiurus nebulosus*) (Cuerrier 1962). Au lac Saint-Louis, la pêche aux chevaliers se faisait principalement à l'aide de filets maillants (76 et 102 mm de maille étirée) et de trémails (Vladykov 1942a). Il y avait deux saisons de pêche, au printemps, en eau peu profonde, près des tributaires (frayères) et en hiver, à des profondeur de 4,5 à 6,0 m. Vladykov (1942a) indique que les espèces de catostomidés étaient recherchées sur le marché de Montréal et que "la saveur de la chair des Carpes est assez bonne, surtout la Noire, le Ballot et la Carpe de France" (= meunier noir, chevalier de rivière et chevalier cuivré).

Évolution de la perception de la diversité des catostomidés

Dans les années 1810, Le Sueur (1817) a été le premier ichtyologiste, suivi de près par Rafinesque (1820), à s'intéresser sérieusement à la description des catostomidés. Les chevaliers représentent, à l'intérieur de cette famille, un groupe taxinomique difficile (Scott et Crossman 1974). Une majorité d'espèces ont été décrites après 1866, date de la description de Pierre Fortin, et quelques espèces ont même été découvertes au cours des années 1990. Cette courte perspective historique illustre bien la valeur scientifique de la liste des poissons de Pierre Fortin et son caractère avant-gardiste.

Au Québec, l'évolution de la perception de la diversité des huit espèces de catostomidés débute véritablement avec les travaux de Pierre Fortin (1866ab). Il distingue une espèce pour chacun des trois genres et quatre espèces en tout (Tableau 4). Vu sous l'angle de la famille des catostomidés, les travaux subséquents de Provancher (1875) et de Montpetit (1897) sont inintelligibles. Provancher (1875) connaissait les rapports de Pierre Fortin mais sa section sur les catostomidés est, disons-le, fortement inspirée d'Agassiz (1855). Il faudra attendre la liste des poissons du fleuve Saint-Laurent préparée par Evermann et Kendall (1902) pour voir évoluer quelque peu notre connaissance des catostomidés. Essentiellement, ces auteurs citent les cinq descriptions de Fortin en utilisant une nomenclature actualisée et y ajoutent le chevalier blanc. Comme déjà mentionné, Evermann et Kendall (1902) associent incorrectement le chevalier cuivré au chevalier rouge. Le nom scientifique donnée par Fortin au meunier noir, sans doute influencé par la présence de plaques blanchâtres sur le museau, entraînera une grande confusion dans la littérature. En effet, "*Catostomus tuberculatus*" est synonyme d'*Erimyzon*, de telle sorte que l'on persistera pendant longtemps à inclure un sucet (*Erimyzon* sp.) parmi les espèces québécoises sur la base du spécimen décrit par Pierre Fortin (Provancher 1875; Evermann et Kendall 1902; Evermann et Goldsborough 1907; Halkett 1913; Mélançon 1936; Scott et Crossman 1974). La grande taille du spécimen de Fortin (483 mm) et la présence d'une "ligne latérale, bien distincte et presque droite" (Fortin 1866b) excluent pourtant une telle interprétation.

Par la suite, Mélançon (1936), probablement inspiré par la liste d'Evermann et Kendall (1902), présente exactement les mêmes six espèces, mais la présence du chevalier rouge est clairement établie (Tableau 4). Quelques années plus tard, soit en 1941, l'Office de Biologie du Québec entreprend une étude pour mesurer l'impact des catostomidés sur le succès de reproduction des espèces d'intérêt sportif du lac Saint-Louis (Préfontaine 1942). Napoléon Lalumière, un pêcheur de "carpes", informe alors les biologistes de la présence de neuf espèces différentes de catostomidés dans la rivière Châteauguay et le lac Saint-Louis (Vladykov 1942a; Vladykov et Legendre 1942). La variété appelée "piccolo" désignait probablement le mâle aux tubercules "piquants" de l'une des cinq espèces de chevaliers (Tableau 4). La "carpe jaune" et le "ballot" seront ensuite identifiés respectivement comme des chevaliers jaune et de rivière par Vladykov (1942b). Quant à la "carpe de France", elle ne correspond à aucun autre poisson dans la littérature récente. La paternité de la découverte scientifique du chevalier cuivré donne alors lieu à une course fébrile entre Vianney Legendre et Vadim Vladykov, deux piliers historiques de l'ichtyologie au Québec (Mongeau et al. 1986). Legendre publie sa description dans le numéro d'octobre-novembre 1942 du Naturaliste canadien alors que celle de Vladykov restera à l'état de manuscrit (A new catostomid genus, *Macropharynx*, found in the St. Lawrence River region). Legendre et ses collaborateurs croient d'abord qu'il s'agit de la même espèce que celle rapportée par Valenciennes sous le nom de *Catostomus carpio* (Cuvier et Valenciennes 1844) et lui donne le nom de *Megapharynx valenciennesi* (Legendre 1942).

En 1946, Cuerrier et al. présentent la première liste complète de nos huit espèces de catostomidés (Tableau 4). Ces auteurs mentionnent également une forme naine du meunier rouge (*C. catostomus nannomyzon*). A l'époque, l'identité exacte du *Megapharynx valenciennesi* suscite toujours le débat. Il devient de plus en plus clair qu'il s'agit d'une espèce totalement différente et inconnue à la science. En 1952, Legendre désigne le chevalier cuivré comme nouvelle espèce sous le nom scientifique de *Moxostoma hubbsi* en référant à sa description originale de 1942 (Legendre 1952). Les recherches menées subséquemment dans les provinces canadiennes et les états américains frontaliers confirment le caractère endémique de l'espèce dont la répartition se limite au sud-ouest du Québec (Legendre 1964).

Origine des noms génériques vernaculaires

D'une façon générale, l'utilisation du terme "carpe", pour désigner les catostomidés, prédomine jusqu'au début du dix-neuvième siècle au Québec. Cette pratique reflète l'absence d'une véritable distinction entre les différentes espèces de catostomidés. Par la suite, le carpe est enveloppée de plusieurs qualificatifs (noire, de rapide, ronde, soldat, franche, etc) et l'on voit apparaître progressivement des noms distinctifs pour les différents genres. Dans leur journal d'expédition des rivières Saint-Maurice et au Lièvre, Ingall et al. (1830) listent 11 poissons dont la "carpe blanche" et la "carpe rouge". Le terme de meunier, actuellement utilisé pour le genre *Catostomus*, est d'origine française. Il était employé autrefois pour désigner d'une façon imprécise certains cyprins (Cuvier 1834). Son utilisation pour nos catostomes indigènes découle du comportement de fraie des meuniers comme le suggère ce passage d'André-Napoléon Montpetit (1872) : "Avec la carpe se mêlent des meuniers qui vont frayer aux abords des moulins...". Dans la littérature, le terme de meunier semble avoir été réservé pendant longtemps au meunier rouge (Fortin 1866b; Montpetit 1872, 1897; Legendre 1952). Le terme "couette", utilisé pour désigner le genre *Carpiodes*, est d'origine québécoise et découle de "poisson à couette" (Mélançon 1936). Ce nom fait référence à la plus grande longueur des premiers rayons de la nageoire dorsale. L'utilisation du nom français "brème" prédominera toutefois dans les écrits québécois, de Fortin (1866b) à Legendre (1952), et fait référence à un cyprinidé européen. L'origine du terme "chevalier" est récente (Branchaud et al. 1998*). D'un point de vue taxinomique, le genre *Moxostoma* regroupe "les catostomes à grandes écailles" (Legendre 1953). Le terme "chevalier" s'inspire directement de ce caractère morphologique en faisant allusion aux armures métalliques portées jadis par les chevaliers, les grosses écailles jouant ici le même rôle de protection. L'aspect métallique (couleur) des écailles de ce groupe de poissons a d'ailleurs inspiré certains noms vernaculaires comme "chevalier cuivré", "moxostome doré", "silver redhorse" et "golden redhorse".

Il serait beaucoup trop long de faire la revue exhaustive des noms utilisés pour chaque espèce, une analyse que nous limitons au chevalier cuivré. Fortin (1866b) emploie le terme "carpe blanche" comme nom vernaculaire canadien dans sa description du chevalier cuivré. Il est possible que cette expression ait été empruntée au nom commercial utilisé alors pour désigner certains catostomidés (voir Richardson 1836). Dans son rapport de 1864, Fortin est le premier à écrire le terme "carpe de France". Il semble que ce nom ait été utilisé par la suite d'une façon générale pour désigner les grosses espèces de moxostomes, dont le chevalier cuivré (Montpetit 1872, 1897; Provancher 1875; Mattews 1887). Après avoir listé les principales espèces d'intérêt sportif rencontrées dans la région montréalaise, Mattews (1887) écrit ceci : "On pourrait ajouter à cette liste, bien d'autres espèces, dignes de figurer dans l'escarcelle et le panier du pêcheur, tels que le bar, le crapet, le brochet, la carpe de France, le mulet, etc". Le terme "carpe de France", lorsqu'utilisé par les pêcheurs commerciaux, devient progressivement spécifique au chevalier cuivré. De 1942 à 1952, c'est principalement sous ce nom que l'on désigne l'espèce (Vladykov 1942a; Vladykov et Legendre 1942; Legendre 1942; Cuerrier et al. 1946). Dans sa deuxième édition des *Poissons de nos eaux*, Mélançon (1946) le dénomme "carpe de Valenciennes", un nom qui ne sera pas repris par la suite. Legendre (1952), inspiré par la livrée nuptiale de l'espèce, introduit pour la première fois le qualificatif "cuivre" en le nommant le "moxostome cuivre". Ce nom prévaudra ensuite de 1952 à 1973 (Legendre 1952, 1953, 1964). Dans une présentation donnée au 31e congrès de l'ACFAS, Mongeau et al. (1964) utilisent le nom de "carpe cuivre". A la suggestion de Vianney Legendre, l'appellation "suceur cuivré" sera employé pour la première fois dans *Freshwater fishes of Canada* publié en 1973. Dans la version française parue l'année suivante (Scott et Crossman 1974), le "suceur cuivré" perd son accent aigu et devient le "suceur cuivre", une terminologie qui sera utilisée en alternance avec celle de "suceur cuivré" jusqu'au début des années 1980. Depuis la publication de l'étude sur la biologie des *Moxostoma* du Richelieu (Mongeau et al. 1986), le nom de "suceur cuivré" a été utilisé d'une façon systématique jusqu'en 1998.

Le volonté de changement de nom, de suceur cuivré à chevalier cuivré, repose sur des motifs de bioconservation (Branchaud et al. 1998*). La connotation à la fois péjorative et sexuelle du vocable suceur rendait l'espèce fort peu sympathique aux efforts de conservation. Le terme "suceur" s'inspirait de la forme particulière de la bouche et, à ce titre, n'était pas très spécifique au genre *Moxostoma*. Il entraînait également une certaine confusion avec le mot anglais "sucker" utilisé pour désigner les espèces du genre *Catostomus*. De plus, le terme "suceur", associé à la position ventrale de la bouche, laissait croire faussement que les espèces de ce genre occupent la niche écologique des nécrophages et des détritivores.

L'évolution de la nomenclature vernaculaire reflète certes notre connaissance de la diversité mais également notre appréciation générale des espèces. Ainsi, il y avait la commune "carpe à cochon" (= chevalier rouge) (Montpetit 1897; Mélançon 1946) remplie de petites arêtes, menu de la basse-cour et la noble "carpe de France" agréable au goût, au menu des auberges. L'image généralement positive des catostomidés semble avoir basculé avec l'envahissement progressif de la carpe (*Cyprinus carpio*). A la fin du dix-neuvième siècle, l'implantation de la carpe était vivement souhaitée au Québec (Montpetit 1897). Comme ce fut le cas aux États-Unis et en Ontario, l'idée surfaite des vertus de l'espèce, la pêche aux mauvaises saisons et le

TABLEAU 4. Évolution de la perception de la diversité des catostomidés au Québec. Les cellules grises signifient que la présence de l'espèce n'est pas clairement établie par l'auteur.

Fortin 1866	Evermann et Kendall 1902	Mélançon 1936	Vladykov et Legendre 1942	Cuerrier, Fry et Préfontaine 1946	Legendre 1952	Noms scientifiques et vernaculaires actuels
Sclerognathus cyprinus	*Carpiodes thompsoni*	*Carpiodes cyprinus*	*Carpiodes cyprinus*	*Carpiodes cyprinus*	*Carpiodes cyprinus*	*Carpiodes cyprinus* Le Sueur 1817 Couette
Catostomus forsterianus	*Catostomus catostomus*	*Catostomus catostomus*	*Catostomus catostomus*[a]	*Catostomus catostomus*[a]	*Catostomus catostomus*[a]	*Catostomus catostomus* Forster 1773 Meunier rouge
Catostomus tuberculatus	*Catostomus commersonii*	*Catostomus commersonii*	*Catostomus commersonii*	*Catostomus commersonii*	*Catostomus commersoni*[b]	*Catostomus commersoni* Lacépède 1803 Meunier noir
	Moxostoma anisurum	*Moxostoma anisurum*	*Moxostoma anisurum*	*Moxostoma anisurum*	*Moxostoma anisurum*	*Moxostoma anisurum* Rafinesque 1820 Chevalier blanc
	Moxostoma aureolum ?	*Moxostoma aureolum*	*Moxostoma aureolum*	*Moxostoma aureolum*	*Moxostoma aureolum*	*Moxostoma macrolepidotum* Le Sueur 1817 Chevalier rouge
			Moxostoma sp. Le ballot	*Placopharynx carinatus*	*Moxostoma carinatum*	*Moxostoma carinatum* Cope 1870 Chevalier de rivière
			Moxostoma sp. La carpe jaune	*Moxostoma rubreques*	*Moxostoma valenciennesi*	*Moxostoma valenciennesi* Jordan 1885 Chevalier jaune
Catostomus macrolepidotus			*Moxostoma* sp. La carpe de France	*Megapharynx valenciennesi*	*Moxostoma hubbsi*	*Moxostoma hubbsi* Legendre 1952 Chevalier cuivré
	Erimyzon sucetta oblongus	*Erimyzon sucetta oblongus*	*Moxostoma* sp. Le piccolo			

[a]Ces auteurs mentionnent également une forme naine (*C. catostomus nannomyzon*).
[b]Cet auteur mentionne également une forme naine (*C. commersoni utawana*).

manque d'informations relatives à sa préparation culinaire ont transformé cette perception populaire positive en mépris (Adams et Hankinson 1928; Mélançon 1946; MacCrimmon 1972). Les préjugés sur la carpe se sont rapidement propagés et elle est devenue un bouc émissaire de la dégradation des habitats aquatiques. Cette situation a certainement nui, par association à la carpe, à l'appréciation générale des catostomidés, à leur valeur économique et à la perception de leur diversité.

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Documents cités

Branchaud, A., A. D. Gendron, J. F. Bergeron et P. Dumont. 1998. Proposition de changement de nom du suceur cuivré. Québec, ministère de l'Environnement et de la Faune, Service de l'aménagement et de l'exploitation de la faune, Longueuil. Lettre adressée à Gilles Harvey et datée du 21 janvier 1998. 6 pages.

Fortin, P. 1873. Lettre adressée à l'Abbé Hamel (Recteur de l'Université Laval) et datée du 8 août 1873. Archive du Séminaire de Québec.

Littérature citée

Adams, C. C., et T. L. Hankinson. 1928. The ecology and economics of Oneida Lake fish. Bulletin of the New YorK State College of Forestry at Syracuse University (Volume 1, number 4a) & Roosevelt Wild Life Annals 1: 241–548.

Agassiz, L. 1855. Synopsis of the ichtyological Fauna of the Pacific slope of North America, chiefly from the collections made by the U.S. Expl. Exped. under the command of Capt. C. Wilkes, with recent additions and comparisons with eastern types. American Journal of Sciences and Arts 19(55): 71–99; (56): 215–231.

Austin, F. W. G. 1866. On some of the fishes of the St. Lawrence. Transactions of the Literary and Historical Society of Quebec 4: 103–120.

Boucher, P. [1664] 1964. Histoire véritable et naturelle des moeurs et productions du Pays de la Nouvelle-France vulgairement dite le Canada. Société Historique de Boucherville, Boucherville, Québec. 415 pages.

Champlain, S. de. [1598–1632] 1870. Oeuvres de Champlain. 6 tomes. Édité par C.-H. Laverdière. Imprimé au Séminaire par Geo.-E. Desbarats. Québec. 1478 pages.

Comité d'intervention. 1995. Plan d'intervention pour la survie du suceur cuivré (*Moxostoma hubbsi*). Québec, ministère de l'Environnement et de la Faune, Direction de la faune et des habitats. Envirodoq EN950159. 48 pages.

Cope, E. D. 1870. A partial synopsis of the fishes of the fresh waters of North Carolina. Proceedings of the American Philosophical Society 11: 448–495.

Cuerrier, J.-P. 1962. Inventaire biologique des poissons et des pêcheries de la région du lac Saint-Pierre. Le Naturaliste canadien 94: 193–214.

Cuerrier, J.-P., F. E. J. Fry, et G. Préfontaine. 1946. Liste préliminaire des poissons de la région de Montréal et du lac Saint-Pierre. Le Naturaliste canadien 73: 17–32.

Cuvier, G. 1834. The animal kingdom arranged in conformity with its organization, with supplementary additions to each order, by Edward Griffith. Volume 10. The class Pisces by the Baron Cuvier, with supplementary additions, by Edward Griffith, F.R.S., &c. and Lieut.-Col. Charles Hamilton Smith, C.H., K.W., F.R., L.S.S., &c. &c. Whittaker and Co. London. 680 pages.

Cuvier, G., et A. Valenciennes. 1828. Histoire naturelle des poissons, tome deuxième. P. Bertrand, éditeur. Paris. 490 pages.

Cuvier, G., et A. Valenciennes. 1844. Histoire naturelle des poissons, tome dix-septième. P. Bertrand, éditeur. Paris. 497 pages.

De Kay, J. E. 1842. Zoology of New-York, or the New-York Fauna. Part IV. Fishes. W & A White & J. Visscher. Albany, New York. 415 pages.

Dionne, N.-E. 1905. Inventaire chronologique des livres, brochures, journaux et revues publiés en langue française dans la Province de Québec, de 1764 à 1904. Mémoires et Comptes Rendus de la Société Royale du Canada, seconde série, volume supplémentaire 10: 1–175.

Dionne, N.-E. 1906. Inventaire chronologique des livres, brochures, journaux et revues publiés en langue anglaise dans la Province de Québec, de 1764 à 1906. Mémoires et Comptes Rendus de la Société Royale du Canada, seconde série, volume supplémentaire 12: 1–228.

D'Urban, W. S. M. 1859. Observations on the natural history of the Valley of the River Rouge, and surrounding Townships in the counties of Argenteuil and Ottawa. Canadian Naturalist and Geologist 4: 252–276.

Dymond, J. R. 1964. A history of ichthyology in Canada. Copeia 1964: 2–33.

Evermann, B. W., et E. L. Goldsborough. 1907. A check list of the freshwater fishes of Canada. Proceedings of the Biological Society of Washington 20: 89–120.

Evermann, B. W., et W. C. Kendall. 1902. An annotated list of the fishes known to occur in the St. Lawrence River. Pages 227–240 *dans* U.S. Commission of Fish and Fisheries. Part XXVII. Report of the Commissioner for year ending June 30, 1901.

Forelle, F. 1856. On the classification of fishes. With particular reference to the fishes of Canada. Canadian Naturalist and Geologist 1: 275–283.

Forster, J. R. 1773. An account of some curious fishes, sent from Hudson's Bay. Philosophical Transactions of the Royal Society of London 63: 149–160.

Fortin, P. 1863a. List of the cetacea, fishes, crustacea, and mollusca, which now inhabit and have inhabited the canadian shores of the Gulf of St. Lawrence, and are the object of fishing operations, whether on a large or small scale, and which are used as bait, &c., &c. Pages 109–124 *dans* Annual reports of Pierre Fortin, Esq., magistrate, in command of the expedition for the protection of the fisheries in the Gulf of St. Lawrence, during the seasons of 1861 and 1862. Hunter, Rose & Lemieux. Quebec. 124 pages.

Fortin, P. [1863b] 1868. Liste des cétacés, des poissons, des crustacés et des mollusques, qui fréquentent et habitent ou ont habité les côtes canadiennes du Golfe St. Laurent, et qui y sont l'objet de pêches plus ou moins considérables, et qui servent d'appâts, etc., etc. Pages 113–129 *dans* Rapports annuels de Pierre Fortin, Ecr., magistrat, commandant l'expédition pour la protection des pêcheries dans le Golfe St. Laurent, pendant les saisons de 1861 et 1862 (traduction française du rapport de 1863). Hunter, Rose et Lemieux. Québec. 129 pages.

Fortin, P. 1864a. Continuation of the list of fish of the Gulf and River St. Lawrence. Pages 60–72 *dans* Fisheries appendices from the annual Report, for 1863, of the Hon. Wm. McDougall, Commissioner of Crown Lands. Statements of fisheries branch, superintendents' reports, Capt. Fortin's report, synopsis of fishery overseers' reports, &c., for the year 1863. (Sessional paper number 5). Hunter, Rose & CO. Quebec. 76 pages.

Fortin, P. 1864b. Suite de la liste des poissons du Golfe St. Laurent et des rivières qui s'y déchargent. Pages

66–79 *dans* Appendices des pêcheries du rapport annuel pour 1863, de l'hon. Wm. McDougall, Commissaire des terres de la Couronne. États de la division des pêcheries, rapports des surintendants, rapport du Capitaine Fortin, extraits des rapports des gardes-pêche, etc., pour l'année 1863. (Document de la session numéro 5). Hunter, Rose et Lemieux. Québec. 83 pages.

Fortin, P. 1865a. Continuation of the list of fishes found in the Gulf of and River St. Lawrence. Pages 61–69 *dans* Annual report of Pierre Fortin, Esq., stipendiary magistrate, commander of the expedition for the protection of the fisheries in the Gulf of St. Lawrence, on board "La Canadienne", during the season of 1864. (Sessional paper number 25). Hunter, Rose & Co. Quebec. 80 pages.

Fortin, P. 1865b. Continuation de la liste des poissons du Golfe et du Fleuve St. Laurent. Pages 65–73 *dans* Rapport annuel de Pierre Fortin, Ecr., magistrat stipendiaire pour la protection des pêcheries dans le Golfe St. Laurent à bord "La Canadienne," pendant la saison de 1864. (Document de la session numéro 25). Hunter, Rose et Lemieux. Québec. 84 pages.

Fortin, P. 1866a. Continuation of the list of fishes taken in the Gulf and River St. Lawrence. Pages 69–79 *dans* Annual report of Pierre Fortin, Esq., stipendiary magistrate in command of the expedition for the protection of the fisheries in the Gulf of St. Lawrence, on board "La Canadienne," during the season of 1865. (Sessional paper number 36). Hunter, Rose & Company. Ottawa. 79 pages.

Fortin, P. 1866b. Continuation de la liste des poissons du Golfe et du Fleuve St. Laurent. Pages 72–84 *dans* Rapport annuel de Pierre Fortin, Ecr., magistrat stipendiaire pour la protection des pêcheries dans le Golfe St. Laurent à bord "La Canadienne," pendant la saison de 1865. (Document de la session numéro 36). Hunter, Rose et Lemieux. Québec. 84 pages.

Gaboriault, V. 1974. Charles-Eusèbe Dionne naturaliste. Société Historique de la Côte-du-Sud. La Pocatière. Cahier d'histoire numéro 9. 144 pages.

Gill, T. 1865. Synopsis of the fishes of the Gulf of St. Lawrence and Bay of Fundy. Canadian Naturalist and Geologist 2: 244–266.

Günther, A. 1868. Catalogue of the acanthopterygian fishes in the collection of the British museum, Volume 7. Taylor & Francis. London. 512 pages.

Halkett, A. 1913. Check list of the fishes of the Dominion of Canada and Newfoundland. C. H. Parmelee. Ottawa. 138 pages.

Herbert, H. W. 1850. Frank Forester's fish and fishing of the United States and British Provinces of North America. Stringer & Townsend. New York. 359 pages.

Ingall, F. L., W. Nixon, et **J. Adams.** 1830. Journal d'une expédition nommée pour explorer l'étendue de pays entre la rivière Saint-Maurice et la rivière au Lièvre. Pages 51–281 *dans* Rapport des commissaires nommés en vertu de l'Acte de la 9e Geo. IV, Chap. 29, pour explorer cette partie qui se trouve entre les rivières Saint-Maurice & Ottawa, et qui est encore demeurée déserte et sans culture. Neilson & Cowan. Québec.

Le Beau, C. (1738) 1966. Avantures du Sr. C. Le Beau, avocat en parlement, ou voyage curieux et nouveau, parmi les sauvages de l'Amérique septentrionale, première partie. Johnson Reprint Corporation. New York. 370 pages.

Legendre, V. 1942. Redécouverte après un siècle et reclassification d'une espèce de Catostomidé. Le Naturaliste canadien 69: 227–233.

Legendre, V. 1952. Les Poissons d'eau douce. Tome 1. Clef des poissons de pêche sportive et commerciale de la province de Québec. Société canadienne d'écologie. Montréal. xiii + 84 pages + 80 figures.

Legendre, V. 1953. Les poissons d'eau douce de la province de Québec: liste des espèces, groupes écologiques, historique, nomenclature, annotations. The freshwater fishes of the Province of Quebec: list of the species, ecological groups, history, nomenclature, annotations. Pages 190–294 *dans* Québec, Ministère de la Chasse et des Pêcheries. Neuvième rapport de l'Office de Biologie.

Legendre, V. 1964. Les vivants au Québec: les découvertes récentes. Pages 170–186 *dans* Québec, Ministère du Tourisme, de la Chasse et de la Pêche, Service de la Faune du Québec. Rapport numéro 3.

Legendre, V., J.-R. Mongeau, J. Leclerc, et **J. Brisebois.** 1980. Les salmonidés des eaux de la plaine de Montréal. I. Historique, 1534–1977. Québec, Ministère du Loisir, de la Chasse et de la Pêche, Direction régionale de Montréal, Rapport technique 06–27. 280 pages.

LeMoine, J. M. 1863. Les pêcheries du Canada. Atelier typographique du Canadien. Québec. 146 pages.

Le Sueur, C. A. 1817. A new genus of Fishes, of the order Abdominales, proposed, under the name of *Catostomus*; and the characters of this genus, with those of its species, indicated. Journal of the Academy of Natural Sciences of Philadelphia 1(5): 88–96; (6): 102–111.

MacCrimmon, H. R. 1972. La carpe au Canada. Ottawa, Environnement Canada, Office des recherches sur les pêcheries du Canada, Bulletin 165. 101 pages.

Mattews, G. H. 1887. Les diverses espèces de poissons autour de Montréal. Pages 241–246 *dans* J. M. LeMoine. Chasse et Pêche au Canada. N. S. Hardy, libraire-éditeur. Québec.

Mélançon, C. 1936. Les poissons de nos eaux, première série. Librairie Granger. Montréal. 128 pages.

Mélançon, C. 1946. Les poissons de nos eaux, deuxième édition. Librairie Granger. Montréal. 250 pages.

Mongeau, J.-R., P. Dumont, et **L. Cloutier.** 1986. La biologie du suceur cuivré, *Moxostoma hubbsi*, une espèce rare et endémique à la région de Montréal, Québec, Canada. Québec, Ministère du Loisir, de la Chasse et de la Pêche du Québec, Direction régionale de Montréal, Rapport technique 06–39. 135 pages.

Mongeau, J.-R., P. Dumont, L. Cloutier, et **A.-M. Clément.** 1988. Le statut du suceur cuivré, *Moxostoma hubbsi*, au Canada. Canadian Field-Naturalist 102: 132–139.

Mongeau, J.-R., V. Legendre, et **A. Courtemanche.** 1964. Redécouverte après 21 ans d'une espèce de poisson endémique de la région de Montréal, la carpe de France ou carpe cuivre, *Moxostoma hubbsi* (résumé). Annales de l'ACFAS 30: 68.

Montpetit, A.-N. [1872] 1991. Le Buisson. Pages 19–30 *dans* Des figures historiques: Jane Ellice et André-Napoléon Montpetit. Collection À Fleur de Siècle. Département d'Anthropologie de l'Université de Montréal, Montréal, Québec.

Montpetit, A.-N. 1897. Les poissons d'eau douce du Canada. C.-O. Beauchemin & Fils. Montréal. 552 pages.

Nash, C. W. 1908. Manual of vertebrates of Ontario. Legislative Assembly of Ontario. Toronto. 122 pages + 107 pages.

Nettle, R. 1857. Salmon fisheries of the St. Lawrence and its tributaries. John Lovell. Montréal. 144 pages.

Ostéothèque de Montréal. 1984. Analyse zooarchéologique des ossements provenant de site Place Royale, Montréal (BjFj-3). Ostéothèque de Montréal, Inc., Département des Sciences de la Terre, Université du Québec à Montréal, Rapport numéro 4. 63 pages.

Potvin, D. 1952. Le roi du golfe. Le Dr. P. E. Fortin, ancien commandant de la "Canadienne". Éditions du Quartier Latin. Québec. 181 pages.

Préfontaine, G. 1942. Sommaire des travaux du ministère de la Chasse et des Pêcheries de Québec pour l'année 1941. Pages 12–32 *dans* Rapport de la station biologique de Montréal et de la station biologique du Parc des Laurentides pour l'année 1941. Fascicule 1. Institut de Biologie, Université de Montréal, Montréal, Québec.

Préfontaine, G. 1946. Le développement des connaissances scientifiques sur les pêcheries maritimes et intérieures de l'est du Canada. Pages 391–454 *dans* Esdras Minville, éditeur. Pêche et Chasse. Éditions Fides. Montréal.

Provancher, L. 1875. Faune canadienne. Les poissons. Le Naturaliste canadien 7: (4) 98–108; (5) 129–134; (6) 161–170; (7) 193–198; (8) 225–232; (9) 257–263; (10) 289–296; (11) 321–327; (12) 361–363.

Rafinesque, C. S. [1820] 1899. Ichthyologia Ohiensis or Natural history of the fishes inhabiting the River Ohio and its tributary streams, preceded by a physical description of the Ohio and its branches. The Burrows Brothers Co. Cleveland, Ohio. 175 pages.

Richardson, J. 1836. Fauna Boreali-Americana; or the zoology of the northern parts of British America: part third. The fish. Richard Bentley. London. 327 pages.

Richardson, L. R. 1935. The fresh-water fishes of South-Eastern Quebec. Thèse de doctorat, Université McGill, Montréal, Québec. 196 pages.

Scott, W. B., et **E. J. Crossman.** 1974. Poissons d'eau douce du Canada. Ottawa, Environnement Canada, Office des recherches sur les pêcheries du Canada, Bulletin 184. 1026 pages.

Small, H. B. 1865. The animals of North America. Series II. Fresh-water fish. M. Longmoore & Co. Montréal. 72 pages.

Stewart, W. B. 1997. A life on the line. Commander Pierre-Étienne Fortin and his times. Carleton University Press, Ottawa, Ontario. 218 pages.

Storer, D. H. 1839. Report on the ichthyology and herpetology of Massachusetts. Pages 1–202 *dans* Reports on the fishes, reptiles and birds of Massachusetts. Dutton and Wentworth. Boston, Massachusetts.

Vladykov, V. D. 1942a. Observations sur les "carpes" (Catostomidés) dans la rivière Châteauguay. Pages 369–375 *dans* Rapport de la station biologique de Montréal et de la station biologique du parc des Laurentides pour l'année 1941. Fascicule 3. Appendice VI. Institut de Biologie, Université de Montréal, Montréal, Québec.

Vladykov, V. D. 1942b. Two fresh–water fishes new for Quebec. Copeia 1942: 193–194.

Vladykov, V. D., et **V. Legendre.** 1942. Liste des poissons observés dans la rivière Châteauguay, et leurs noms locaux. Pages 338–342 *dans* Rapport de la station biologique de Montréal et de la station biologique du parc des Laurentides pour l'année 1941. Fascicule 3. Appendice II. Institut de Biologie, Université de Montréal, Montréal, Québec.

Whiteaves, J. F. 1869. Zoological notes. Canadian Naturalist and Quarterly Journal of Science 4: 101–103.

Yarrell, W. 1841. A history of British fishes, Volume 1, deuxième édition. John Van Voorst. London. 464 pages.

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Book Reviews

Zoology

Endemic Bird Areas of the World: Priorities for Biodiversity Conservation

By Alison J. Stattersfield, Michael J. Crosby, Adrian J. Long, and David C. Wege, with maps by Andrew P. Rayner. 1998. Birdlife International, Wellbrook Court, Girton Road, Cambridge CB3 0NA, U.K. 846 pp., illus. U.S. $60.

This book is the culmination of a mammoth ten-year program by the Secretariat of Birdlife International to provide a sound basis for identifying priorities in conservation. With biodiversity being lost at an increasing rate, and the finances and knowledge needed to arrest this loss in short supply, there has been a vital need for a system to establish priorities among a multitude of conflicting demands.

One approach to establishing priorities is to concentrate attention on areas that have particularly high biodiversity, especially those that harbour endemic species. An indication of the value of such an approach is that, for example, some 20% of the world's birds are confined to only 1% of the world's land area. In practice, however, developing a sound, scientifically-based system of priorities on a world scale is an enormous challenge. This program's goal was to do just that, and this volume presents its results. It provides both a methodology for identifying areas of outstanding endemism, and a survey of the 218 areas it identifies.

The rationale for the project's approach and the details of its methodology are covered in introductory chapters, starting with a discussion on biodiversity and of the need to set priorities for conservation. The project uses birds as "indicator species", identifying those with narrow distributions, species which consequently are particularly vulnerable to extinction. By plotting the ranges of such endemic birds, one can also identify areas of high endemism. The degree to which the data thus developed can be applied to other life forms is reviewed, and patterns of endemism in animals and plants are compared (there's an overlap of some 60%, indicating that Endemic Bird Areas (EBAs) have considerable significance to other groups).

The approach to identifying EBAs is to plot the ranges of all the world's restricted-range landbird species, defined as those with breeding ranges of 50 000 km^2 or less. An EBA is then defined as an area that wholly encompasses the breeding range of at least two such species. Not unexpectedly, areas such as islands and continental refugia, especially in the tropics, predominate in the EBAs. Using these criteria, over 25% of all birds have restricted ranges, with the ranges of 93% of these encompassed by 218 EBAs. These species include 74% of all threatened bird species, and 85% of EBAs have one or more threatened species. The EBAs are then assessed in terms of their biological importance to birds and of the degree to which they are threatened, to produce an overall priority ranking.

Another chapter discusses the opportunities for conserving EBAs, reviewing the various international treaties that are relevant, as well as Birdlife International's own programs. The introductory section then concludes with a series of regional introductions, giving a broad overview of each continent in turn, and the EBAs it contains.

The main meat of the book is the detailed accounts of the world's Endemic Bird Areas. Each account presents a concise summary of information on the area, including a map, summary tables of the restricted-range species present and their status, descriptions of the area, and current threats and conservation needs. At the end of the book are one-paragraph accounts of 138 Secondary Areas, which support one or more restricted-range species, but which do not meet the criteria for full EBA designation. Appendices list restricted-range species by family and – with the relevant EBAs – by country. There are 31 pages of references, and an index to the restricted-range species covered.

The data in this impressive volume should prove invaluable to conservationists and decision-makers working in the international field. Few, however, are likely to read it from cover to cover, and its direct relevance to Canada is small. It is of more general interest for its methodology, and in giving a broader perspective to other Birdlife International projects, such as the Important Bird Areas program.

Probably we should be pleased that none of our birds qualify as restricted-range species, and indeed Southern California is the only EBA north of the Mexican border, although there are four secondary areas (in Michigan, Texas, and two in Alaska). The real problems lie elsewhere, and their seriousness and scope can perhaps be appreciated by the thought that the country with the largest number of restricted-range species – 403 – is Indonesia. These accounts make depressing reading, but at least the challenges are now clearly defined.

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North American Bird Folknames and Names

By James Kedzie Sayre. 1996. Bottlebrush Press, Foster City, California. 291 pages. U.S. $24.95.

In 1957 I invested 25 cents to purchase Bulletin 149 of the National Museum of Canada. In this 74-page bulletin, W. L. McAtee, retired from 37 years service as biologist and editor with the U.S. Biological Survey, shared his life-long collection, *Folk-names of Canadian Birds*. The species' names were indexed, but the frustrating thing was that the folk-names were not indexed. Thus, if someone phoned to ask me what a "spirit duck" or a "butter-ball" was, I could look up Bufflehead in McAtee to confirm that my recollection was correct. However, "spider bird" (a folk name for the Cedar Waxwing in the Maritimes and for both the Yellow and Myrtle Warblers in Manitoba) would have stumped me and forced me to scan the entire publication.

Now James Kedzie Sayre, an amateur birdwatcher in California, has come to my rescue. He obtained access to McAtee's complete, 1697-page unpublished manuscript, covering all of North America, and has consulted other literature sources. The result is a list of the known folk names of birds from the United States and Canada. Sayre's number of folk names must be at least twice that given by McAtee.

Sayre's index alone (covering English, Latin, and folk names) is worth the price of his book, but sadly in my first ten tries, I hope unrepresentative, I found four errors. I also found typographical errors scattered through the text.

In future, if I begin with a folk name of a bird, and don't know what species it represents, I will ascertain the species from Sayre. I will then read the account in McAtee, who gives what Sayre does not, the derivations and explanations of the names, and also the Canadian province from which each name derives.

I hope Sayre has sufficient sales to allow production of a corrected and expanded edition some time in the future. For example, from Coues' 1894 text, in addition to the Bay-winged Sparrow, now the Vesper Sparrow, he could add the Bay-winged Longspur (now McCown's) and the Bay-winged Summer Finch, now the Rufous-winged Sparrow.

Meanwhile, Sayre's new book will be a handy reference for anyone interested in folk names of birds.

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North American Owls: Biology and Natural History

By Paul A. Johnsgard (with watercolours by Louis Agassiz Fuertes). 1988. Smithsonian Institution Press, Washington, D.C. 295 pp., illus. + plates. U.S. $24.95.

This book has recently been re-released in a paper bound version. Despite being a decade old, *North American Owls* is still a book that is surprisingly useful as a reference for several owl species; although its value would obviously have been greatly enhanced had it been updated. It provides a good literature review of published studies of owls up to 1987. However, for several owl species, notable: Great Grey, Boreal (Tengmalm's), Burrowing, Flammulated, and in particular Spotted owls, the amount of newer published information is now considerable and the ecology for some of these species has essentially been re-written since the late 1980s.

The book includes a series of very handsome watercolour plates by L. A. Fuertes, and a number of excellent colour photographs that illustrate well owl facial discs. There are two parts to the book: the first deals with evolution, classification, and comparative morphology, physiology, behaviour, and reproductive biology, and a second section discusses individual species' biology. The book closes with a key to the species.

The bulk of the book is devoted to relating natural history of the various species under the headings of range (with map), measurements, subspecies, weights, description, identification, vocalizations, habitats and ecology, movements, foods, social behavior, breeding biology, evolutionary relationships, and conservation status. As noted above, the value of the ecological information is now obsolete for some species, but for other less-studied species such as Long-eared Owls, the information is still useful. With the possible exception of Northern Spotted Owls, owls are an extremely poorly researched group of species. This is somewhat surprising, given the spurt of recent interest among many academics in applied wildlife research. It is further surprising, given the recent commotion over the need to identify reliable "indicators" of forest condition, that these top carnivores which clearly integrate changes at forest and landscape scales, have received so little attention. In the United States, it took a listing of Spotted Owls under their Endangered Species Act to promote a strong research effort. In Ontario, Barred Owls have all but been extirpated across the southern areas of the province, and are uncommon in the rest of the province. They are thought to prefer older conifer-dominated forests, that are being logged in rapid fashion, yet they are on no one's research agenda.

Although the book is well-researched, the section entitled "Comparative ecology and distribution" contains some curious errors. For example, Table 3 shows ranges of weights of preferred prey as large (>500 g), medium (250-500 g) and small (<250 g). Snowy Owls, (that prefer lemmings); Spotted Owls (that prefer flying squirrels and small rodents), and Barred Owls (that eat mostly small rodents) are incorrectly listed as preferring large prey items. On page 33, Great-horned Owls and Snowy Owls are reported as being sympatric. In fact, the only area where their ranges overlap is the northwestern coast of Alaska, where they separate spatially, and on more than 95% of their respective ranges these two species are allopatric. However, these small errors are insufficient to detract from the general quality of the book.

I found the book to be highly readable and provided valuable insights into the ecology of owls, but I wished that it had been revised with current information. The book is a recommended volume for anyone with an interest in these elusive yet interesting birds.

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A Guide to the Nests, Eggs, and Nestlings of North American Birds

By Paul J. Baicich and Colin J. O. Harrison, illustrated by Andrew Burton, Philip Burton, and Terry O'Nele, and egg photographs by F. Greenaway and Clark Sumida. Second Edition 1997. Academic Press, 525 B Street, Suite 1900, San Diego, California 92101-4495. 348 pp., illus. $31.95, U.S. $22.95.

This is the second edition of Colin Harrison's 1978 guide, with essentially the same format and the same plates as its predecessor. For the reader who is unfamiliar with the plan of the first edition, the core of the book consists of accounts of the nests, eggs, and nesting characteristics of some 669 species. Species coverage typically starts with a brief statement on nesting sites and habitat, and then covers nest, breeding season, eggs, incubation, nestling, and nestling period. There are 64 coloured plates of eggs and a selection of about 150 chicks and nestlings, supplemented by sketches of typical nests scattered through the text. Introductory sections provide useful general information on the topics covered in the body of the text, together with hints on nest findings and details on nest record schemes. Finally, there is a set of rather general identification keys for nests, eggs, nestlings, and chicks.

The format may be the same but the changes are comprehensive, reflecting not only the many taxonomic changes since 1978 and the species added to the North American list in that period, but including up-to-date information on nesting. The first edition relied heavily on Bent's *Life Histories of North American Birds* for its information, but the current text recognizes a wide range of sources, and is correspondingly comprehensive. Even the plates have been rearranged to conform to current taxonomy, with some additions including four Shiny Cowbird eggs. The text illustrations have been considerably expanded with the addition of sketches by Terry O'Nele.

The inevitable comparisons will be with the two volumes by Hal Harrison in the Peterson Field Guide series. These offer photographs of the nests and eggs (most in colour), a feature lacking the in the present book, and are a more compact size. In all other aspects, however, this volume emerges a clear winner: not only is it much more up-to-date, but the material is much more comprehensive and detailed and the egg illustrations are larger and clearer. In fact, these three books now complement one another very well, and anyone working in this field will wish to have all three. In all, a job well done, and highly recommended as a concise and up-to-date summary of matters associated with bird nests and nesting.

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Vancouver Birds in 1995

By Kyle Elliott and Wayne Gardner. 1997. Vancouver Natural History Society. Vancouver, 92 pp., illus. $14.95.

This volume is the latest offering from the Vancouver Natural History Society (VNHS), and like their previous publications is of a high standard. As the title suggests, it presents a summary of all bird species observed during the 1995 calendar year within the Vancouver Checklist area. An impressive 70 000 records were submitted by 193 observers, through the VNHS Bird Alert line, the four (five in 1995) local Christmas Bird Counts (CBCs), banding data from Sea Island, and various bird surveys. The high degree of participation in all these projects reminds me once again, of just how dynamic the Vancouver birding community is.

An introductory section defines the Vancouver Checklist area and provides the rationale for this report: "to record the seasonal occurrence, abundance, and distribution of each bird species so that future changes will be discernible." As a statistical snapshot of one birding year, this book provides some interesting reading. However, if similar summaries are issued on a periodic basis, then this work would be very valuable as a management and conservation tool. Comparisons over time of a species distribution and abundance will provide hard data with which to make informed decisions regarding conservation concerns.

A short section of the book reviews local birding projects and provides data on mist net captures at the Sea Island banding station, as well as results of the monthly bird surveys at Maplewood Flats in North Vancouver. Sixteen pages of very good photographs highlight some of the species observed in 1995. The main body of the book, however, is taken up with the summary of the 282 species found that year.

The authors note that this list summarizes "arrival dates, migration numbers, high counts, departure dates, noteworthy records, and the number of reports made for each species." CBC data is also included where applicable. Each species is listed first by its common name, followed by the scientific name, the 4-letter species code, and seasonal abundance; an asterisk indicates breeding. The average arrival date is given for some spring migrants. Tables showing the median number of birds per month at one or all of four primary birding locations, Iona and Sea Islands, Reifel Refuge, and Jericho Park, are given for 97 species.

While Vancouver birders won't need any prompting to buy this book, I highly recommend it to anyone contemplating a birding trip to the area. It gives a fair indication of the relative ease or difficulty of finding some of those west coast specialties including Crested Myna, Tufted Duck, Pacific Golden Plover, Wandering Tattler, and Gray-crowned Rosy Finch. And just to whet the appetite one can note the rarities found that year, such as Emperor Goose, White-tailed Kite, Bar-tailed Godwit, Slaty-backed Gull, and Ash-throated Flycatcher, and aspire to similar finds. Used together with a bird-finding guide, such as another excellent VNHS publication, *A Bird Watching Guide to the Vancouver Area* (1993), there should be no trouble planning a trip to see the maximum number of species.

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The Federation of Alberta Naturalists Field Guide to Alberta Birds

By Bruce McGillivray and Glen P. Semenchuk. 1998. Federation of Alberta Naturalists, P.O. Box 1472, Edmonton T5J 2N5. 350 pages, 313 colour photographs, 296 maps, 2 diagrams. $24.95 + $4.00 shipping.

Wow! Just when I thought that existing field guides had given us everything one could reasonably expect, along comes a new guide for one province, Alberta, that is chock-full of useful new innovations.

For the first time ever, the beginner is given four criteria, each rated on a scale of 1 to 3, for habitat, sight, sound, and behavior. For example, the Sprague's Pipit rates three checkmarks for sound and three for habitat (native grassland), two for behaviour (flying high) and only one for sight. Most *Empidonax* flycatchers get three for sound and one or two for habitat, but Alder, Willow, and Hammond's get none at all for sight! The Canvasback and Ring-necked Duck each earn only one rating, a three for sight. The Ruffed Grouse and Killdeer both receive three each for sight and sound, two for behavior and one for habitat. Bonaparte's Gull collects three for habitat, two each for sight and behavior, and one for sound. The Gray Jay earns three each for behavior and sight, two for sound and one for habitat. The American Dipper obtains three each for habitat and behavior, two for sight and one for sound. Clearly these are subjective ratings, but they ring true, and should be a tremendous help to the novice in deciding whether to identify the bird by sight, by sound, by habitat, or by behaviour.

Other features also differ from previous field guides. The Latin names of each species are explained. There is a photo of the egg, giving its length and width, for each species. Date bars across the bottom of each page show the time of year that species may be expected. There is a box to check and a space to enter the date of one's first sighting. Page tabs and the species name are in the same colour; for example, red for flycatchers. Finally, the new Latin names of the 7th AOU Check-list are already incorporated, and, with a few minor exceptions, the sequence of species is that of the new check-list (though the change in the generic name of the Stilt Sandpiper was overlooked). This is an admirable achievement, since this field guide appeared only a month or two after the Check-list. Together, these innovations are successful, and warrant purchase of this book by almost everyone in western Canada. The keen birder will need an extra copy to keep in the glove compartment of the car.

An amazing amount of information is packed into each page. The book is the ideal size for a field guide. The style is informal, sometimes almost chatty, providing all sorts of interesting but little-known facts, often with commentary and even some editorializing about what the future might hold. Some nice points: the Least Flycatcher is the most urban of flycatchers; the Philadelphia Vireo is the commonest vireo in the Chinchaga Valley of northern Alberta; Snow Buntings "turn and whirl in unison like flocks of sandpipers." There is a personal suggestion, after mention of Dippers inhabiting mountain streams so cold they defy belief, that the reader "step into a high mountain stream with bare feet and see how long you can stand it." Under the elusive Swamp Sparrow, we are told "you cannot study what you cannot see."

For what we call birdwatching, McGillivray and Semenchuk say that birdlistening is really closer to the truth. They admit frankly that it is usually impossible to separate *Empidonax* flycatchers by sight alone. They caution that Willow and Alder Flycatcher vocalizations are often mistaken, one for the other. Yet they don't explain how difficult it is to render bird songs in English syllables, and they fail to advise which record or tape has the best rendering of each Alberta species' song or note. Apart from exceptions such as the Killdeer and chickadee, one simply cannot take the syllables rendered here and identify the species in the field; even the well-known "che - bek" for the Least Flycatcher is simply an aide memoire. And some of the renditions familiar to oldtimers, such as "witchery, witchery" for the Yellowthroat, "see, see, sue-zee" for the Black-throated Green Warbler, "sweet, sweet, sweeter-than-sweet" for the Yellow Warbler, and "pee-ter, pee-ter" for the Baltimore Oriole, are rendered in other, to me less preferable, syllables.

A few useful points of sight identification, such as the more pointed head of the Barrow's Goldeneye, as compared to the Common Goldeneye, and the shorter bill of the Ross's Goose, are not mentioned.

There are a few serious errors. The Lewis's Woodpecker, known to have bred at Jasper, and the newly-arrived House Finch, are not illustrated or mapped. The 4-page Alberta bird-list, designed to photocopy and use on a one-day trip, omits nine species including the American Robin, although the adjacent 13-page Alberta Species List appears to be complete. Unacceptable alpha four-letter codes (e.g. COGR for Common Grackle) used in the first edition of Pyle et al.'s *Identification Guide to North American Passerines*, but since discredited and corrected in Pyle's second version, have been perpetuated for 11 species, while new alpha codes have been invented for 24 species. This can lead only to serious confusion for those who use these four-letter codes to save time or space.

There are also occasional minor errors and infelicitous statements. Alberta grasslands are east, not west of the Rocky Mountains (page 8). It seems inappropriate to speculate in a field guide, without any evidence, that the Eurasian Wigeon "is nesting on this continent." Harlan's Hawk is not the most common subspecies of the Red-tailed Hawk in Alberta. The Ferruginous Hawk is not endangered, and it has even been removed from the less serious "threatened" category. If, indeed, the Northern Hawk Owl has been seen to "sometimes construct its own crude nest of interwoven branches," this new fact should be shared in a scientific journal, not in a field guide. I would not describe the Gray Catbird tail as "blue." Vagrant Black-throated Blue Warblers have moved west, not east. William Fraser Tolmie, not William Frank Tolmie, is honoured in the Latin name of MacGillivray's Warbler.

English usage is sometimes careless. When "fewer" is meant, "less" is used. It is disconcerting to find a species is referred to as both "it" and "they" within the same paragraph. The authors are overly fond of "this" as an isolated pronoun and as an adjective.

The maps are generally good, but I would have liked use of additional dots to show extraliminal locations, and a little more care in marking the range of a few species. Based on my experience in the province to the east, I simply do not believe that the Veery and the Swainson's Thrush share almost identical ranges. Surely the Veery extends farther south than the Swainson's Thrush?

The colour photographs vary in quality, and are not always helpful for identification, especially when only adult male plumage is shown for most species. As one example, the Rufous Hummingbird photo is an uncharacteristically deep shade of red. Hence one must still carry another field guide to make up for this deficiency.

Any new model of car or book has a few initial defects. In this case, they can be ironed out in the inevitable second printing. The original, innovative approach of this book is a prodigious achievement. One hopes its format can be extended to other provinces.

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Habitats for Birds in Europe: A Conservation Strategy for the Wider Environment

By G. M. Tucker and M. I. Evans. 1997. Burlington Press (Cambridge) Ltd., Cambridge, U.K. (Birdlife Conservation Series No. 6). 464 pp. maps. U.S. $45.00.

BirdLife Conservation publications are a series devoted to bird conservation in Europe. This volume contains the results of a comprehensive survey of European bird habitats carried out by a wide network of scientists and volunteers. The Habitat Working Groups (HWG) are based in countries west to Iceland, east to Russia, and south to Turkey and the recommended strategies for conservation are the result of 10 years of work. Eight major types of habitats were surveyed: Marine seas: (a) north and west European seas, (b) Macaronesian (c) Mediterranean and Black seas; Coastal habitats; Inland wetlands; Tundra, mires, and moorland; Boreal and temperate forests; Lowland Atlantic heathland; Mediterranean forest, shrubland and rocky habitats; and Agricultural: (a) grassland, (b) montane, (c) steppic, and (d) wet grassland. The eight main chapters of the book identify the threats to each of the above habitats and the broad conservation policies and actions which are needed to preserve them. Appendix 1 is a summary of the priority status of 520 bird species in different habitats in Europe and their international legal status, followed by appendices giving habitat requirements and predicted impact of threats to birds.

The HWG have formulated nine conclusions and made nine recommendations for conserving threatened habitats. These are placed at the beginning of the book (before the main body of text) where they cannot be overlooked. They occupy only three pages, and are crystal clear in outlining what action is required to preserve bird life in Europe. Wide ranging conservation and land use legislation has already been passed by the European Community and is summarized, but implementation of the laws is lax and there is little genuine willingness by land users to cooperate voluntarily. One interesting recommendation is made: the onus for proving sustainable environmental land use should be initiated by the users, not as a result of challenges by environmental organizations.

BirdLife International is sponsored by the Royal Society for the Protection of Birds, Vogelbescherming Netherland, and Fondation Hans Wilsdorf (Montres Rolex). The Canadian Nature Federation and Bird Studies Canada are partners in the BirdLife Important Bird Areas programme, and are carrying out similar studies in Canada. The presentation of results of the thorough research given in this valuable book can be a model for similar studies.

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Birds of Liberia

By Wolf Gatter. 1997. Pica Press, Sussex, England. 320 pp., illus.

Birds of Somalia

By J. S. Ash and J. E. Miskell. 1997. Pica Press, Sussex, England. 336 pp., illus.

The recorded knowledge of ornithology in Africa has taken a giant step forward with the publication of these two books. *Birds of Liberia* (*Liberia*) and *Birds of Somalia* (*Somalia*) are good purchases for researchers and amateur enthusiasts alike. They will be immensely useful not only to African and Gulf area birders, but to Europeans who want to know the wintering and migration patterns of their summer birds. Equally important are the questions raised about knowledge and conservation. Both areas have immense human and political issues and conservation does not have the profile it needs. These books now establish a reference and raise the profile of the plight of birds. If the current peace in Liberia and Somalia can be maintained then it will be possible, using these published data as a base, to move knowledge and conservation forward.

Both books have a generally similar style with a relatively consistent format. They are not field guides and are best described as a cross between an annotated checklist and a distributional atlas. Each book describes the vegetation, geology, climate, conservation, and breeding seasons, followed by the main section – a distributional atlas. While each book has an ornithological history of their respective countries, *Liberia* adds a political history. By comparing these sections from each book the reader will see the contrast and similarities of Africa. Liberia is a new country, artificially created and part of the equatorial forested zone (although the forest is disappearing rapidly). It has far more rain in the coastal margin than Vancouver. Somalia, under various forms and names, has existed since the days of the Pharaohs. It is a dry place, on par with the drier areas of the Canadian prairies.

Liberia has 21 small maps showing site locations, topography, rainfall, vegetation, and migration, of which six show aspects of forest cover. The book concentrates on the ecology and stresses the relationship of birds to the forest system. *Liberia* was written by a forester so there is a substantial amount of information on trees. I found this somewhat heavy going because the author rarely uses a common name like "mangrove" and I am not familiar with the scientific names of tropical African trees. This bias for forestry does not occur in this annotated text in the atlas section.

This book covers, by my estimate, about 630 species, of which 612 have a range map. As I read *Liberia* I was more surprised by what I did not see, than the records given. For example, several of the birds of prey (hawks and owls) are rare or have questionable records. I would have expected more confirmed data. Also, there are anomalies in the distributions recorded. For example, Striped Kingfisher has only two records, yet the African Dwarf Kingfisher, a bird with a similarly wide distribution, is "not uncommon". This, I am sure, reflects the difficulty of working in a developing country, especially one that has just emerged from civil war. (The author feels some birds benefitted from the war. I suppose when you're busy shooting people you cannot waste time and ammunition on wildlife!)

I did pick out a couple of minor errors. The author lists the African Goshawk (*Accipiter tachiro*) as a common resident. The form found in Liberia is now split as a separate species, the Red-chested Goshawk (*A. toussenelii*). Under African Scops Owls the author references a map on page 127. There isn't a map.

Both books have five colour plates, all but one by Martin Woodcock. Woodcock is a well-known, fine bird artist, who has illustrated many books. *Somalia* has 25 species depicted, including all the endemic or near endemic species (these are mostly larks). As the other African guides rarely have good illustrations of these species these plates are a welcome contribution to bird art. *Liberia* has 30 species shown on the plates, plus another 58 in a photographic section (not all in colour). This section also has 29 habitat colour photographs and some black-and-white historical and other support photographs. The bird photographs do not follow a pattern, so I suspect they represent those birds the author or his son managed to photograph well.

Somalia is more of a birder's book. For example, there are good full-page topography, vegetation, geology, and place location maps. The text indicates that the data were collected with an atlas in mind, so the result is a fairly uniform coverage. Indeed much of the data were collected by Ash and Miskell. *Somalia* covers 654 species (300 breeding and 165 rarities), all of which are mapped. There is no photographic section, which is unfortunate, as I enjoyed and appreciated the habitat photographs in *Liberia*. *Somalia* can easily be used to understand the potential birds in any particular area and the likelihood a person would have of seeing them. Three lists at the back of the book (species recorded offshore, species requiring confirmation, and species recorded at the border) alert field observers to the potential additions they could make to the record. There is also a list of the seven endemics.

I do not believe that there has been one week in the last year when I could not find a television program on Thomson's Gazelles being hunted by some large predator. This gazelle has a limited distribution in Kenya and Sudan and film-makers have practically photographed it to death. Perhaps these new books will alert nature programmers to some wonderful birds that live in other areas of Africa (not to mention Ditabag – a graceful Somalian gazelle – and the cute species of monkeys which live on the Liberian side of Africa. They may even push the film-makers into leaving the comforts of Kenya so they can bring new species into our homes!

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Wildlife of the Tibetan Steppe

By George B. Schaller. 1998. The University of Chicago Press, Chicago, Illinois 60637. 373 pp., illus., maps. U.S. $55.00.

The detailed research results of nine expeditions to the Tibetan Plateau over ten years are presented in *Wildlife of the Tibetan Steppe*. It is estimated that nomads first moved to the Plateau about 30 000 years ago and until 1959 the wildlife populations remained stable. All that changed with the Chinese occupation, which altered the lifestyle and demands on the indigenous people. In 1959, nomads were resettled in the northern part of the Plateau, where few had lived before. Roads were built into remote places and the wildlife was slaughtered in large numbers.

George Schaller, who has been involved in wildlife conservation efforts in Central Asia since 1967, was commissioned by the Chinese Ministry of Forestry to collaborate on a survey of large mountain mammals of Tibet, parts of Mongolia, and western China: to determine the current status and distribution of species, particularly snow leopards. The region is so vast, and the survey season so short, that it could only be sampled. However, even the sampling produced interesting and disturbing results. Wildlife is disappearing at an alarming rate for two reasons. The populations kill more wildlife than before to supplement their traditional food sources and to pay new taxes, and increased agricultural use of land has encroached on wildlife habitat. Schaller estimated that there are 12 million domesticated yaks and about 30 million sheep living unfenced. As a result of the survey, the Tibet Autonomous Region government has established the Chang Tang Reserve, which was the main study area. It is roughly 334 000 square kilometres in area and is almost as large as Germany. A chapter for each large mammal gives the results of the scientific survey, including Tibetan Antelope, Argali, Blue Sheep, Gazelle, Wild Yak, White-lipped Deer, Wild Bactrian camel, and the Tibetan Wild Ass. One recommendation for wildlife preservation is to persuade the nomads to harvest wool and medicinal products from living animals rather than by killing them. This particularly applies to the Tibetan antelope (Chiru) whose wool, called Shahtoosh, surpasses even vicuna in its quality and commands astronomical prices. Schaller believes that live collection of the wool could save the Chiru from extinction, and provide nomads with income at the same time.

The book concludes with guidelines for conservation action in the Chang Tang Reserve.

George Schaller's prose is always eminently readable, even in a scientific book such as this. Scientists and non-scientists will welcome this detailed study of the mammals of a remote part of the world. The popular account of the expeditions has been published in *Tibet's Hidden Wilderness*.

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Parrots: A Guide to the Parrots of the World

By Tony Juniper and Mike Parr. 1998. Yale University Press, New Haven and London. 584 pp., illus.

Parrots is a very fine book indeed, giving comprehensive coverage of the species of parrots of the world. It is fully illustrated with high quality colour plates, supported by detailed text and effective range maps. It is somewhat unfortunate, then, that this book has been published so close in time to Volume 4 of *Handbook of the Birds of the World (Sandgrouse through Parrots to Cuckoos)*[1]. The *Handbook* has already established a fine reputation, and those who have purchased the preceding volumes will want to continue their collection. There will not be many who will want to pay for two new, first-rate parrot books.

The almost simultaneous arrival of these two books means there will be comparisons and champions for both works. To begin the comparison, the authors of *Parrots* often use different English names to those in the *Handbook* (for example, Solomon vs. Ducorps Parrot). The systematic sequence is also very different. This makes one of my problems with the book all the more important. For some reason the authors have chosen to list by the scientific, specific name and their choice of English name only in the index. So when I looked for the Solomon Corella I had to search for *ducorpsii* to find Ducorp's Cockatoo rather than the generic name of *Cacatua*. Similarly a bird I have always seen named Major Mitchell's Cockatoo *(C. leadbeateri)* is labeled Pink Cockatoo. Unlike *Handbook*, *Parrots* does not give the alternative English names in the index. This made tracking down a particular species much more difficult.

How well do the plates compare? That is difficult to answer, in part because a single species of parrot can vary widely in colour. *Parrots* is more detailed, shows more of the variations within a single species and has more thorough coverage of subspecies. Five artists were involved so there is a variation in quality. Sometimes I thought an entire plate did not match the average quality for the book (e.g., Plate 37 - *Neophema* Parrots), while in other plates that individual representations were off (the green of the Alexdrine Parrot is too dark, and the Regent Parrot is more yellow than shown).

The range maps in *Parrots* are larger and more precise than in the *Handbook*. Whether they are more accurate is open to question. Certainly the *Handbook* maps conform better with the published literature. For example, ranges the Western-Little-Long-billed Corella group of Australian cockatoos are confusing. It appears the Western range is overdrawn, while the Little and Long-billed are undersized.

The authors have made a few unique choices. For example, the Red-collared Lorikeet (*Trichoglossus rubritorquis*) is treated as a separate species from the 20 or so subspecies of the highly variable Rainbow Lorikeet. No explanation is given why they have taken this action. Conversely the Adelaide Rosella is treated as a hybrid (*Platycercus elegans x P. flaveolus*), again without explanation. It is more normally treated as a subspecies *(Platycercus elegans adelaidae)* or a full species (*Platycercus adelaidae*).

This is the first, full-scale book on parrots since Forshaw's[2] epic tome published over twenty years ago. While this is still a great book with fine illustrations by William Cooper, the information in Forshaw is becoming more and more dated. This is particularly true of status and distribution data. So Juniper and Parr's new contribution is most welcome. If your interest is in parrots or you are planning to travel to areas with parrots then this work offers some advantages over the *Handbook*. It is much smaller; while not quite pocket size (25x18x4 cm) it is certainly easier till fit in a suitcase than the much larger *Handbook*. The added detail on plumages and distribution will help in the field. I would recommend this book to one other important group of people, law enforcement officers. Those fighting the sad trade in wild parrots now have a powerful tool to help them in their work.

References

1. Josep del Hoyo, Andrew Elliot, and Jordi Sargatal. *Editors*. 1996. Handbook of the Birds of the World: Volume 4 Sandgrouse to Cuckoos. Lynx Edicions, Barcelona.
2. Forshaw, J. M. 1973. Parrots of the World. T. F. H. Publications, Inc., New Jersey.

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Whitetail Spring

By John J. Ozoga. 1996. Willow Creek Press, Minocqua, Wisconsin. 144 pp. $29.50 US.

Whitetail Summer

By John J. Ozoga. 1997. Willow Creek Press, Minocqua, Wisconsin. 144 pp. $29.50 US.

Whitetail Spring and *Whitetail Summer* are the third and fourth volumes in the "Seasons of the Whitetail" series (also included are *Whitetail Autumn* and *Whitetail Winter*). The series focuses on the biology of the Whitetail Deer, *Odocoileus virginianus* and the books contain text written by veteran whitetail researcher John Ozoga, matched with beautiful photographs of deer and related nature scenes.

The books are both divided into topical sections that follow the seasonal development of deer. *Whitetail Spring* contains sections on five major topics: social behaviour, nutrition and feeding, antler growth, fawn-rearing behaviour, and fawn mortality. *Whitetail Summer* contains sections on: societal structure, summertime scent-marking, fawn development, summer behaviour, and antler development. The information contained in the text of the chapters is a very good introduction to deer biology. It is not however, intended to be a thorough review of the field. Indeed, Ozoga himself claims in the acknowledgements that these are "coffee-table books", meaning that the text is very well illustrated with photographs.

Ozoga writes with an easy style and provides us with a very accessible means of learning about deer biology. I found the text interesting although occasionally I felt as though I needed more detail. In these cases I was left unfulfilled because other (more detailed) published works are not cited from within the text; instead a bibliography of selected references is included. A glance through the references demonstrates an emphasis on Ozoga's own research.

"Seasons of the Whitetail" is not a series targeting biologists or naturalists explicitly. Rather, I see these books as intended for a broader audience, including the uninitiated reader, and for this audience it is a very attractive package. More experienced naturalists will enjoy the photographs but may be left looking for more from the text.

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Polar Dance: Born of the North Wind

By Thomas D. Mangelsen with text by Fred Bruemmer. 1997. Images of Nature, Omaha, Nebraska. 264 pp., illus. U.S. $65.00.

Although even the most dedicated naturalist may wonder why the world needs another book on Polar Bears, a leaf through Thomas Mangelsen's collection of stunning photographs in this large coffee-table book will make you appreciative that the publishers of *Polar Dance* went to the effort. Thomas Mangelsen was named "Wildlife Photographer of the Year" in 1994 by the British Broadcasting Corporation – after looking through *Polar Dance* the only question that remains is, "why does this man not have a closet full of such awards?" This is a superb collection of images of Polar Bears and their environment, with considerable emphasis on the habitats in which they live.

The great strength of this book is that Mangelsen did not feel compelled to fill his viewfinder with the bears. Rather, he seems to generally prefer framing them against the immense backdrops of frozen polar sea – in many of these images the bears are mere specks against a vast horizon. This provides a much better perspective of the Polar Bear's world than has been previously available in books of this sort.

Mangelsen says in the preface that his objective was "to catch the essence of the Polar Bear and the Arctic in its many moods, textures, and seasons." He has succeeded, and his ability to capture and use Arctic light pervades the book. A photograph of a sow and her two cubs walking across a stretch of ice surrounded by parahelia ("sun dogs") rates as one of the most striking images I've ever seen. Any photographer would be proud to have taken just one of the photographs assembled in this collection. To have 280 of such quality is simply an astounding accomplishment. In the book's foreword, bear biologist Frank Craighead wonders how Mangelsen managed to position his subjects just where he wanted them to be. The reader will share Dr. Craighead's wonder. Amateur shutterbugs will appreciate such mastery of the camera and Mangelsen's obvious ability to be in the right place at the right time. It is also a testament to Mangelsen's skill that this entire collection was taken since he first saw a Polar Bear in 1987.

Fred Bruemmer is no stranger to readers of books about the Canadian Arctic and about Polar Bears. His book *The Long Hunt* (Ryerson Press, 1969) documented his experiences on a six-week Polar Bear hunt in 1967 with Inuit from Grise Fiord, and he then followed with *World of the Polar Bear* (Key Porter Books, 1989). In those two books he emphasized the relationships that exist between humans and Polar Bears, from ancient times to the present. In *Polar Dance* Bruemmer's text occupies a mere 41 of the book's 264 pages and in them he looks at the Arctic through the bears' eyes. In four chapters that parallel the seasons, Bruemmer interlaces accounts of a lone male and of a mother and two cubs with descriptions of the environment in which they live. The text flows well and keeps the reader's interest. The publishers should be commended for double-spacing the test, which makes the calligraphic script that much easier to read.

The naturalist who wishes to read and learn about Polar Bear evolution, ecology, status, and conservation will still be much better served reading *Polar Bears* (University of Michigan Press, 1988) by Canadian polar bear researcher Ian Stirling. But the naturalist who wishes to simply sit back and dream about the world of the polar bear will not find a finer book of images to spark the imagination. *Polar Dance* is therefore recommended for those who do not mind paying a handsome price for a high quality collection of the finest in wildlife photography.

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Ancient Marine Reptiles

Edited by Jack M. Callaway and Elizabeth L. Nicholls. 1997. Academic Press, Orlando. 501 pp., illus. U.S. $64.95.

Often misconstrued as dinosaurs, marine reptiles are in fact not dinosaurs. They were in some ways the aquatic equivalent of the contemporaneous dinosaurs; each have their own, separate, evolutionary history. Like *Dinosaur Systematics* (Cambridge University Press, 1990), *Ancient Marine Reptiles* is not the be all / end all review of this diverse segment of the reptile class. It is a synopsis of current research in the many areas of marine reptile systematics, evolution, behavior, and biomechanics.

The first section is devoted to the Ichthyosaurs and covers two taxa; the German *Shastasaurus*, and *Mixosaurus* from Switzerland. One chapter examines the rich Ichthyosaur fauna (up to four species) from British Columbia and another examines the tooth placement within various taxa. The three chapters in the second section deal with plesiosaurs; the middle Triassic fauna from Europe is discussed in reference to biogeography, the revamping of *Plesiosaurus* from England, and a brief review of two North American taxa, *Libonectes* and *Dolichorhynchops*. *Desmatochelys lowi*, a marine turtle is described, while two chapters look at biodiversity and biogeography of Cretaceous marine turtles. There are only two chapters on mosasaurs, one a phylogenetic review, the other examines the microstructure of bones. There is less information provided on mesosuchian crocodiles with only one chapter on *Hyposaurus*. The odds and ends section looks at biostratigraphy of marine reptiles, paleobiogeography, the lack of suspension feeders among marine reptiles, and the last chapter ends with a grander evolutionary view of the marine reptile record.

This book is not intended for the general reader, but instead is geared towards a small segment of the paleontological community that encounters marine reptiles in the geological strata. Though highly technical, there are two features of this book that effectively sew the multitude of specific and grander ideas together. First, before each section (Ichthyosaurs, Plesiosaurs, Mosasaurs, marine turtles, and crocodiles) the editors enlisted many of the leading experts to provide shortened historical reviews. This allows the reader at least a cursory understanding of the evolution of the systematics up to present day. For North America this involves re-examining the work of many of the notables in 19th century paleontology: Edward Cope, Othniel Marsh, Samuel Williston, to name a few. One of the most enjoyable sections of *Ancient Marine Reptiles* is Michael Taylor's foreword which briefly outlines marine reptiles in a historical context. Before the discovery of what Owen would later call dinosaurs, many diverse marine reptiles were discovered, collected, exhibited, and studied, each playing a bit part in the emergence of how science viewed fossils.

We are a land acquainted species, familiar with life around us. Creatures from the deep oceans, hidden from our view, still mystify us all, whether in today's fauna, or those from many millions of years ago. *Ancient Marine Reptiles* sheds, if not entirely new light on the aquatic diversity, at least illustrates that there is more the the "Age of Dinosaurs" than dinosaurs, and that weird and wonderful monsters provide unique perspectives on the past.

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BOTANY

Trilliums

Frederick W. Case, Jr., and Roberta B. Case. 1997. Timber Press, Portland, Oregon, 285 pp., illus. U.S.$29.95.

Many are outstandingly beautiful. More than a few have foul odours. The leaves of most compete with the flowers for attention. There are species which can freeze solid and continue to thrive. Hybridization is common, mutations occasionally produce elegant, but sterile, double blossoms. Infection creates transitory loveliness. It is small but the trillium family (Trilliaceae) has much to hold our interest, as a reading of this book soon makes one realize.

A great choice as a gift for anyone with an interest in wildflowers or horticulture, it has an eye-catching dust jacket, is beautifully illustrated throughout, provides interesting information about trilliums in general, contains a detailed field guide to each trillium species and invites one to simply look at, and enjoy, its contents.

The first thing that strikes one, in turning its pages, is the large number of stunning half-page to full-page, fine quality, colour photographs. The 78 plates are truly a feast for the eyes. The glossy pages, however, contain a wealth of other features as well.

With a fondness for trilliums, nurtured in the years I lived in Ontario and by visits to the West Coast, but with limited knowledge of them, I found the introductory first part very helpful with its sections on the history, general nature, relatives, number and origin of species, structure, biology, horticulture and conservation of this family of plants.

The second, larger part of the book is the field guide. It begins with a chapter on taxonomy and is divided into two major sections covering North American and Asian genera. Each section begins with an illustrated key. I found the part on the use of identification keys particularly helpful. At each step of the key there is a small sketch of the most distinctive features to be noted. Each species account contains a colour picture — sometimes several — and a very clear range map, along with an introduction, notes on habitat, season, distribution, habitat, varieties, forms, hybrids, and concluding comments. The horticulture value of each species is assessed. As a naturalist, I appreciated the authors' repeatedly expressed concern for the protection of wild populations. Ample references to other resources, in the Preface and Bibliography, along with a glossary and an index, add to the book's usefulness.

Some may find it a little heavy and unwieldy to use in the field. Amateurs may find the botanical jargon troublesome at times. One gets on to it but I felt there was more of it than is needed, since a "general" as well as a "botanical" readership is envisioned. More information about pollinators would have been appreciated. Yet these are minor criticisms.

Each of the target readers identified by the authors — "advanced amateur botanists, horticulturists, naturalists, and perhaps even trained botanists" — will find much to appreciate in this volume. I suspect, also, that people beyond these categories will pick it up and feel rewarded. It's a book worth having.

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ENVIRONMENT

Lament For An Ocean

By Michael Harris. 1998. McClelland & Stewart. Toronto 342 pp.

This book gives a very solid overview and summary about the processes and policies that eventually resulted into the fishing crisis in Eastern Canadian waters. Although the subtitles "The Collapse of the Atlantic Cod Fishery: A True Crime Story" and "The Ecological Disaster of the Century. The Political Scandal of the Decade" are indeed quite catchy and would not generally imply an excellent read on a scientific topic, they do capture the context of an infamous ecological and ecological failure. As the former publisher of The Sunday Express newspaper in St. John's, Newfoundland, the author, Michael Harris, is well suited to retell the story. He is not afraid of mentioning facts and names. Harris emphasizes the outspoken research by Jeffrey Hutchings and others in the Department of Fisheries and Oceans and describes details of the political scenes, which lead to the Estai crisis, the turbot war and the cod crisis with all its social impacts on Newfoundland and whole Atlantic Canada, including the TAGS program.

The author provides compelling evidence that foreign fishing fleets alone did not destroy the Canadian fisheries and overfish the waters off Newfoundland: the Canadian-controlled waters in the St. Lawrence estuary were almost free of a foreign fishing fleet until the fisheries there crashed; a 200-mile zone off Newfoundland was implemented as early as 1976, within which there were no foreign fleets allowed, but this zone is also considered as being overfished. Certainly, the international fishing access policies to Canadian waters, in particular the French, Spanish and Portuguese, are well covered in this book. Harris indicates that improved economic efficiency did not protect the fish resources from being depleted. Also, he shows that the unfortunate trend towards a few, but large multinational companies, such as fish processing plants, did not allow for a truly creative solution in a market-based competitive system and neglected small-scale fisheries. Harris includes an instructive chapter on the salmon war and draws a comparison between the fisheries in Western and Eastern Canada. Another good point of the book is that the author refers to the interesting relationship between oil prices and fishing efficiency, and he compares the fisheries policies in Norway with the Canadian ones.

The shortcoming of the book is that it does not fully show how severe, or not severe, the fishing crisis in Atlantic Canada really is. Fishing in this area has certainly not stopped, and strangely enough, it even seems to be doing fine in some places; fishing effort just shifted to new target species, is still continuing its old ways, and is now enforced with an approved policy on aquaculture. The value of the book could have been slightly increased by some colour prints, by comparing how Iceland has dealt with an upcoming fisheries crisis, and by elaborating on details of the East Canadian seal hunt and the ecological relationship between seals and cod. Overall, the book overemphasizes some points repeatedly, perhaps the text is 50 pages too long.

However, I fully recommend this book. A comment on the book jacket reads: "... After reading this book, you wouldn't trust the Department of Fisheries and Oceans with your aquarium". We can only hope that books on similar subjects involving scientifically-approved resource overexploitation, which is based on a short-term perspective of the public and their political leaders but not on free and unbiased science, will never need to be written again.

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Nature's Services: Societal Dependence on Natural Ecosystems

Edited by Gretchen C. Daily. 1997. Island Press, Washington, D.C. 392 pp.

In this day and age with news focusing on economic ramifications of human activity, people with an interest in a healthy biosphere find themselves asking or being asked what value does a natural system provide society? One can argue this is a very human interest only view, but it is a view used more and more to provide reasons for some level of protection. The general argument being: the more value to society the greater the need to preserve or conserve. This implies a means to priorize. The priorities are set often using the perceived benefit as justification. How are these benefits or values arrived at?

G. C. Daily has assembled twenty chapters or papers from thirty-two world renown experts which address some of the issues involved in determining benefits or value provided by ecosystems or components. The chapters have been organized to provide, first, a general overview then progress finally to more specific case studies. The chapters found at the intermediate point of this gradient deal with components and major biomes. The reader is provided with references for each chapter as well as an index to utilize for further research. All papers are highly readable and should be understood by readers with minimal technical training. Only a few typos were noted in the text.

As one reads through the book they become aware of the wealth of information which is available. They also are confronted by the enormous gaps which exist in mankind's understanding of the world in which he/she lives. The lack of scientifically based information on which some of these decisions have been made, I'm sure would trouble most. This book provides an insight for those involved in the research field, policy setting or the general consumer.

Dr. Daily has edited a book which (1) provides a history of ecosystem valuation, (2) describes present state of scientifically based information available for major biomes, (3) provides description of some key components and their valuation, and (4) specific case studies of the valuation process. This information is presented in a highly readable fashion. This is a book I would not hesitate to recommend to those involved in the valuation of the world's ecosystem services.

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NEW TITLES

Zoology

†**Bat biology and conservation.** 1998. Edited by T. H. Kunz and P. A. Racey. Smithsonian I. P., Washington. 576 pp., illus. U.S. $60.

*__Biology and evolution of Australian snakes.__ 1997. By A. E. Greer. Surrey Beatty Chipping Norton, Australia. xi + 358 pp., illus. A$82.

†**Birds of Madagascar: a photographic guide.** 1998. By P. Morris and F. Hawkins. Yale University Press, New Haven. xi + 316 pp., illus. U.S. $35.

†**The birds of Sonora.** 1998. By S. M. Russell and G. Monson. University of Arizona Press, Tucson. xii + 362 pp., illus.

*__Birds of Wisconsin.__ 1998. By O. J. Gromme. Revised edition. University Wisconsin Press, Madison. xi + 227 pp., illus. U.S. $75.

The caddisfly family Phryganeidae (Trichoptera). 1998. By G. B. Wiggins. University of Toronto Press, Toronto. 352 pp. $120 in Canada; U.S. $120 elsewhere.

Catalogue of the marine invertebrates of the estuary and Gulf of Saint Lawrence. 1998. By P. Brunel, L. Bosse, and G. LaMarche. Canadian Special Publications Fisheries and Aquatic Sciences No. 126. NRC Research Press, Ottawa. 405 pp. $64.95 in Canada; U.S. $64.95 elsewhere.

Cats of Africa. 1998. By A. Hall-Martin. Smithsonian Institute Press, Washington. 152 pp., illus. U.S. $45.

†**Cowbirds and other brood parasites.** 1998. By C. P. Ortega. University of Arizona Press, Tucson. xvi + 371 pp., illus. U.S. $65.

†**The dawn of conservation diplomacy: U. S.-Canadian wildlife protection treaties in the progressive era.** 1998. By K. Dorsey. University of Washington Press, Seattle. xvi + 312 pp., illus. U.S. $35.

†**The ecological traveler's wildlife guide Costa Rica.** 1998. By L. Beletsky. Academic Press, San Diego. xii + 426 pp., illus. U.S. $27.95.

A guide to the birds and mammals of coastal Patagonia. 1998. By G. Harris. Princeton University Press, Princeton. 251 pp., illus. U.S. $65.

The fishes of the Galapagos Islands. 1997. By J. S. Grove and R. J. Lavenberg. Stanford University Press, Stanford xxi + 863 pp., illus. U.S. $125.

†**Swallow summer.** 1998. By C. R. Brown. University Nebraska Press, Lincoln. xiii + 371 pp., illus. U.S. $16.95.

The handbook of bird identification for Europe and the Western Palearctic. 1998. By M. Beaman and S. Madge. Princeton University Press, Princeton. 784 pp., illus. U.S. $99.50.

*__The life of birds.__ 1998. By D. Attenborough. Princeton University Press, Princeton. 320 pp., illus. U.S. $29.95.

Life on the edge: amazing creatures thriving in extreme environments. 1998. By M. Gross. Plenum Press, New York. xiii + 200 pp., illus. U.S. $25.95.

†**Manual of ornithology: avian structure and function.** 1998. By N. S. Proctor and P. J. Lynch. Reprint of 1993 edition. Yale University Press, New Haven. 352 pp., illus. Cloth U.S. $50; paper U.S. $25.

†**The nature of caribou: spirit of the north.** 1998. By H. J. Russell. Greystone Books, Vancouver. xii + 114 pp., illus. $34.95.

†**The nature of walruses: white-tusked wanderers of the sea.** 1998. By P. Knudtson. Greystone Books, Vancouver. xiii + 114 pp., illus. $34.95.

Principles of animal communication. 1998. By J. W.

Bradbury and S. L. Vehrencamp. Sinauer, Sunderland, Massachusetts. xiii + 900 pp., illus. U.S. $62.95.

†**Rails: a guide to the rails, crakes, gallinules, and coots of the world.** 1998. By B. Taylor. Yale University Press, New Haven. 600 pp., illus. U.S. $49.99.

Seasons of the whale. 1998. By E. Hoyt. Humane Society of the United Sates, Washington. 104 pp., illus. U.S. $19.95.

*__Status and conservation of midwestern amphibians.__ 1998. Edited by M. J. Lannoo. University of Iowa Press, Iowa City. 520 pp., illus. Cloth U.S. $49.95; paper U.S. $29.95.

Botany

*__The flora of Maine.__ By A. Haires and T. F. Vinning. V. F. Thomas, Bar Harbor, 837 pp. U.S. $45.

Flora of Nova Scotia. 1998. Revised by M. Zinck. 3rd edition. Nimbus Publishing, Halifax. 2 volumes.

*__Rare native vascular plants of British Columbia.__ 1998. By G. W. Douglas, G. B. Straley and D. V. Meidinger. British Columbia Ministry of Lands and Parks, Victoria. v + 423 pp. + 3 pp. addendum.

Environment

†**Biogeography.** 1998. By J. H. Brown and M. V. Lomolino. Sinauer, Sunderland, Maryland. xii + 692 pp., illus. U.S. $64.95.

†**Hungry Hollow: the story of a natural place.** 1998. By A. K. Dewdney. Copernicus (Springer-Verlag), New York. xiv + 233 pp. U.S. $26.

Life in the balance: humanity and the biodiversity crisis. 1998. By N. Eldredge. Princeton University Press, Princeton. xv + 224 pp., illus.. U.S. $24.95.

Mexico: adventures in nature. 1998. By R. Mader. John Muir Publications, Santa Fe. U.S. $18.

A natural history of the first four billion years of life on Earth. 1998. By R. Fortey. Knopf, New York. xiii + 346 pp., illus. U.S. $30.

*__Nature's purposes.__ 1998. Edited by C. Allen, M. Bekoff, and G. Lauder. MIT Press, Cambridge. vi + 597 pp., U.S. $30.

People and the earth: basic issues in the sustainability of resources and environment. Cambridge University Press, New York. xxii + 338 pp., illus. Cloth U.S. $80; paper U.S. $32.95.

*__Policy practices for biodiversity in managed forests: the living dance.__ 1998. Edited by F. L. Bunnell and J. F. Johnson. University British Columbia Press, Vancouver. xiv + 162 pp., illus.

Terrestrial ecosystems in changing environments. 1998. By H. H. Shugart. Cambridge University Press, New York. ix + 537 pp., illus. Cloth U.S. $90; paper U.S. $39.95.

†**Views from the Alps: regional perspective on climate change.** 1998. Edited by P. Cebon, H. C. Davies, D. Imboden, and C. C. Jaeger. MIT Press, Cambridge, Massachusetts. xv + 515 pp., illus. U.S. $60.

Which world: scenarios for the 21 century. By A. Hammond. Island Press, Washington. xiv + 306 pp., illus. U.S. $24.95.

†**Wildlife-habitat relationships: concepts and applications.** 1998. By M. L. Morrison, B. G. Marcot, and R. W. Mannan. 2nd edition. University Wisconsin Press, Madison. xxii + 435 pp., illus. U.S. $34.95.

World resources 1998-1999: a guide to the global environment. 1998. By World Resources Institute. Oxford University Press, New York. xii + 369 pp., illus. U.S. $24.95.

Miscellaneous

*__Charles Doolittle Walcott, paleontologist.__ 1998. By E. Yochelson, Kent State University Press, Kent, Ohio. xvi + 510 pp. + plates. U.S. $49.

*__The evolution revolution.__ 1998. By J. Long and K. Mcnamara. Wiley, New York. xiii + 298 pp., illus.

Frankenstein's footsteps: science, genetics, and popular culture. 1998. By J. Turney. Yale University Press, New Haven. ix + 276 pp., illus. U.S. $30.

Life's other secret: the new mathematics of the living world. 1998. By I. Stewart. Wiley, New Nork. xiii + 285 pp., illus. U.S. $24.95.

*__Passionate minds: the inner world of scientists.__ 1997. Edited by L. Wolpert and A. Richards. Oxford University Press, New York. 240 pp., illus. U.S. $37.

Book for Young Naturalists

Animalogy: weird and wacky animal facts. 1998. By R. T. Mullin. Crown, New York. 64 pp., illus. U.S. $9.99.

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J. D. W. Kahl. Lerner, Minneaplis. 64 pp., illus. U.S. $15.95.

Hippos. 1998. By S. M. Walker. Carolrhoda, Minneapolis. 48 pp., illus. U.S. $14.95.

A ladybug's life; A luna moth's life; and **A salamander's life.** 1998. By J. Himmelman. Children's Press, Danbury, Connecticut. each 32 pp., illus. U.S. $23.

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Whales, dolphins, and porpoises. 1998. By M. Carwardine. DK Publishing, New York. 64 pp., illus. U.S. $7.95.

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The world of dinosaurs. 1998. Edited by M. Brett-Surman and T. R. Holtz, Jr. Greenwich Workshop Press, New York. 48 pp., illus. U.S. $19.95.

*Assigned for review
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The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

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Please submit, **to the Editor**, in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

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TABLE OF CONTENTS *(concluded)*

News and Comment

Book Reviews

Mailing date of the previous issues: 112(4): 27 March 1999
113(1): 31 March 1999

THE CANADIAN FIELD-NATURALIST Volume 113, Number 2 1999

Articles

Notes

concluded on inside back cover

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Cover: Mountain Plover, *Charadrius montanus*, nest containing six eggs. Photographed by Stephen J. Dinsmore 2 June 1997, Phillips County, Montana. See note by Dinsmore and Knopf, pages 516–517.

The Canadian Field-Naturalist

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Important Bird and Mammal Records in the Thelon River Valley, Northwest Territories: Range Expansions and Possible Causes

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Norment, Christopher J., Alex Hall, and Paul Hendricks. 1999. Important bird and mammal records in the Thelon River Valley, Northwest Territories: Range expansions and possible causes. Canadian Field-Naturalist 113(3): 375–385.

Included in information on the status of 50 bird species and five mammal species in the Thelon River valley, Northwest Territories are nine northward and three southward breeding range extensions for birds, along with 16 species not previously recorded in the Thelon Wildlife Sanctuary. Thirty of the bird species, along with Red Squirrel (*Tamiasciurus hudsonicus*), Moose (*Alces alces*), Porcupine (*Erethizon dorsatum*), River Otter (*Lutra canadensis*), and Beaver (*Castor canadensis*) were not reported by either J. C. Critchell-Bullock or C. H. D. Clarke during reconnaisances of the Thelon River area during the 1920s and 1930s. Although recent, increased search effort may explain many of these differences, it is likely that the Common Loon (*Gavia immer*), Mallard (*Anas platyrhynchos*), American Widgeon (*Anas americana*), Surf Scoter (*Melanitta perspicillata*), Gyrfalcon (*Falco rusticolus*), Yellow-rumped Warbler (*Dendroica coronata*), Rusty Blackbird (*Euphagus carolinus*), Moose, and Red Squirrel have established breeding populations in the Thelon River area since the 1930s. Several hypotheses may explain northward range expansions, including a recent warming trend at the northern treeline during the 1970s and 1980s. Although apparent changes in the mammalian and avian faunas are consistent with an hypothesis linked to climate change, correlational studies are probably inadequate to link climate change causally with changes in species distribution.

Key Words: Birds, mammals, breeding range expansion, Northwest Territories, Thelon Wildlife Sanctuary, climate change.

The forest-tundra is a landscape mosaic of tree and tundra vegetation covering a vast area of the Northwest Territories (NWT). The forest-tundra extends 2400 km northwest from Churchill, Manitoba, to the Mackenzie Delta in the NWT, with an average width of 145 ± 72 km (Timoney et al. 1992). Because the forest-tundra may be a sensitive indicator of climatic change, interest in the region has risen due to concern over the possible effects of global warming (Zoltai 1988; Timoney et al. 1992). Parts of the region are also the focus of increased exploration for diamonds and minerals and discussions concerning land use (CACNMP 1990), and there is much need for baseline data on the distribution of plant and animal species in the area. However, the isolation of most of the forest-tundra has limited biological research in the region, with the exception of Churchill, where intensive ornithological work has been carried out for many years (Jehl and Smith 1970). Within interior portions of the region, data on the distribution and abundance of birds and mammals are available only for widely separated localities, and often for only single years (see Clarke 1940; Porsild 1943; Manning 1948; Harper 1953; Mowat and Lawrie 1955; McLaren and McLaren 1981; Norment 1985). However, this situation is rapidly changing as a result of environmental assessment studies associated with increasing resource development in the NWT.

This paper summarizes important avifaunal records gathered in 1971–1996 along the Thelon River and its tributaries, including the Elk, Mary Frances, Hanbury, and Clarke rivers (Figure 1). Information is presented on new avian breeding records for the Thelon River Valley, including significant range extensions. Breeding records are also provided for bird species whose ranges include the study area, but for which there are no documented breeding records from within the Thelon Wildlife Sanctuary (TWS). We also present information on migrant or vagrant species occurring outside of their normal range in the NWT. Finally, we document the recent northward range expansion into the TWS of the River Otter (*Lutra canadensis*), Moose (*Alces alces*) and Red Squirrel (*Tamiasciurus hudsonicus*), and provide additional records of Beaver (*Castor canadensis*) and Porcupine (*Erethizon dorsatum*).

Records in the present paper and from Norment (1985) and Kuyt (1980) are compared to those summarized by C. H. D. Clarke (1940) for the TWS. The original boundaries of the TWS extended westward to Artillery Lake, but were shifted eastward in 1956 (CACNMP 1990). Thus we confine our comparisons to areas surveyed by Clarke within the current boundaries of TWS, primarily the lower Hanbury River and the Thelon River between the Hanbury/Thelon junction and Beverly Lake. This region was visited briefly by Clarke in 1936, and more extensively in 1937, when he canoed from the headwaters of the Hanbury River to Baker Lake, 19 June – 20 August (Clarke 1940). Clarke's (1940) account also summarizes the observations of Critchell-Bullock (1931), who traversed the Hanbury and Thelon Rivers in 1924. Although Critchell-Bullock's records were less complete than Clarke's, and probably include several misidentifications (Clarke 1940), they may still provide valuable evidence concerning the presence of species in the study area during the 1920s, and we cite Critchell-Bullock's (1931) records where appropriate.

Study and Methods

The study area includes portions of the Thelon River drainage from the Elk River (62°25′N, 104°48′W) north to Beverly Lake (64°36′N, 100°30′W), including the Mary Frances, Hanbury and Clarke rivers (Figure 1; see for all locations). The section of the Thelon River Valley within the Thelon Wildlife Sanctuary (TWS; formerly the Thelon Game Sanctuary) has been listed as a key migratory bird habitat (Alexander et al. 1991), and as a proposed International Biological Programme ecological site (Nettleship and Smith 1975). Portions of the region lie within the Kazan Upland and Thelon Plain physiographic divisions of the Canadian Shield (Clayton et al. 1977), with the granitic and gneissic uplands of the Hanbury, Elk and Mary Frances drainages giving way to a till-covered plain of low relief in the middle Thelon basin (Bird 1951). Extensive sand dunes occur along the Elk, Hanbury and Clarke rivers. Most of the study area lies within the forest-tundra transition, which includes four vegetation regions: high boreal forest, low subarctic, high subarctic, and low arctic (Timoney et al. 1992). Within the forest-tundra transition zone, tree:upland tundra cover ratios vary from 1000:1 to 1:1000 (Timoney et al. 1992). In addition to the term forest-tundra, as defined by Timoney et al. (1992), we use the term "treeline" to refer to the approximate boundary between tundra and relatively continuous forest, as indicated on 1:500 000 maps. The Thelon River Valley supports extensive stands of White Spruce (*Picea glauca*) and Black Spruce (*P. mariana*), growing in sheltered locations beyond the northern forest border and which extend downriver from the Clarke River junction to Ursus Islands. This forest outlier is surrounded on three sides by upland tundra and connected to continuous forest to the south by scattered spruce stands (Clarke 1940). Five upland plant communities similar to those described by Larsen (1965) are found in the area: rockfield, tussock muskeg, low *Carex* meadow, upland Black Spruce and lowland Black Spruce. A mixed White Spruce-Black Spruce community, with individual trees reaching 18 m, occurs on well-drained sites. Distribution of spruce within the TWS is discontinuous, with stands of 0.1 to 15 ha occurring along drainages, beaches, and dunes.

Avifaunal data were gathered by one of the authors (AH) during annual canoe trips between 1971–1997 along the Thelon River and its tributaries, and by CJN and PH during research on crowned sparrows (*Zonotrichia* spp.) at Warden's Grove, Thelon River, NWT (63°41′N, 104°26′W; hereafter referred to as WG), a forest-tundra site located in the TWS. Residency dates at WG were 21 May–23 July 1989, 27 May–21 July 1990, and 24 May–17 July 1991. Observations from WG supplement earlier records from the TWS made between August 1977 and July 1978 (Norment 1985). Data on mammals were gathered by AH (1971–1997) and CJN (1977–1978, and 1989–1991).

In the annotated bird species list presented below, species are classified as migratory, breeding, or vagrant. Breeding species were classified as possible (PO), probable (PB), or confirmed (CB) according to standardized criteria codes developed for North American breeding bird atlas projects (NORAC 1990). Confirmed breeding species were observed either building nests, with nests containing eggs or young, feeding or accompanied by newly fledged young, or carrying food for young. Categories of relative abundance were based upon recorded data as follows: abundant (> 10/d when present in area); common (3–9/d when present); uncommon (0.1–2/d when present); occasional (seen in most years, but less than 0.1/d); rare (1–2 records). Taxonomic order and nomenclature follows the most recent checklist of the American Ornithologists' Union (1998).

Annotated Species List

Birds

COMMON LOON (*Gavia immer*). CB; common from treeline north to near the Elk River - Thelon River junction, uncommon within TWS. A pair seen with a chick 13 km south of the Clarke-Thelon junction on 31 July 1991, and one seen on a nest on 9 July 1996, 3 km north of Eyeberry Lake. Godfrey (1986) lists Common Loons as breeding ca. 80 km south of Schultz Lake, east of TWS, but these are first breeding records for middle Thelon basin. Not observed by Clarke (1940) in TWS.

GREAT BLUE HERON (*Ardea herodias*). Rare vagrant.

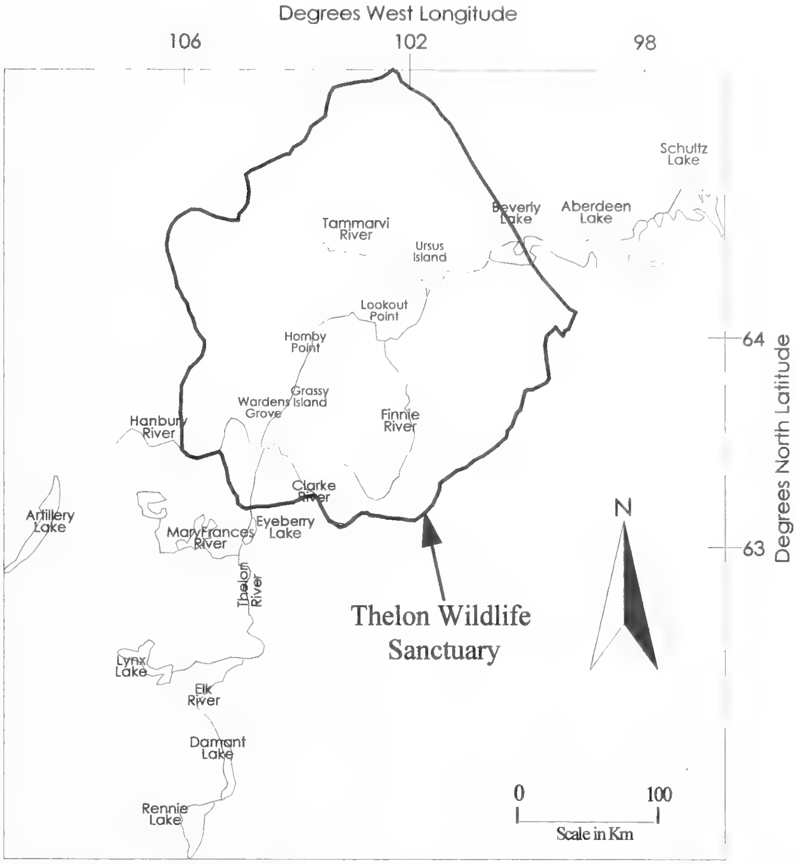

FIGURE 1. Thelon Wildlife Sanctuary, Northwest Territories, and locations mentioned in the text.

One record from Elk River, 15 August 1991, 140 km south of TWS.

GREATER WHITE-FRONTED GOOSE (*Anser albifrons frontalis*). Occasional CB, abundant migrant along Thelon River. Known breeder from TWS (Kuyt 1962a; Godfrey 1986); pair with flightless young on 12 August 1992 just north of Damant Lake along the Elk River extends described breeding range southward ca. 100 km.

CANADA GOOSE (*Branta canadensis*). Occasional CB, abundant migrant along Thelon River from early May (Norment 1985) until late July, when most appear to move downriver at least as far as Beverly and Aberdeen lakes. Breeds in TWS (Clarke 1940), although most Canada Geese in TWS and upper Thelon watershed do not breed there, but move into area to molt (Kuyt 1962b, 1966). However, at least two dozen pairs with flightless young were observed along Thelon River between Eyeberry Lake and Ursus Islands 1971 to 1996. In addition, a small subspecies nests in hundreds along cliffs and steep rock slopes of Clarke River.

BRANT (*Branta bernicla*). Rare vagrant. One on unnamed lake at headwaters of Clarke River, 27 June 1993. Not reported by Clarke (1940).

TUNDRA SWAN (*Cygnus columbianus*). CB. Common along Thelon River between Grassy Island and Ursus Islands. Breeds at Grassy Island in TWS (Clarke 1940), but two pair with flightless young seen on Thelon River at southern boundary of TWS, 29 July 1984, 50 km south of Grassy Island, is southernmost breeding record in Thelon Valley. However, AH recorded two pairs of Tundra Swans, each with two flightless young, within the forest-tundra zone on the upper Dubawnt River just north of Wholdaia Lake, 300 km south of the breeding range in Godfrey (1986), on 26 July 1982.

AMERICAN WIDGEON (*Anas americana*). Uncommon CB. Not seen by Clarke (1940) in TWS, but now observed occasionally along lower Hanbury River and frequently along Thelon River north to Lookout Point (Norment 1985). Seven records of widgeons with flightless young 1984 to1994, from Grassy Island north to Hornby Point, extending known breeding range ca. 130 km north. Early arrival dates 2 June 1989 and 27 May 1991.

MALLARD (*Anas platyrhynchos*). Uncommon CB. Mallards have been recorded in the TWS (Norment 1985), but Clarke (1940) did not observe them and Godfrey (1986) showed the northern limit of breeding range well south of TWS. Seen regularly along Thelon River north to Ursus Islands, with five records of females with flightless young 1977 to 1988, from Eyeberry Lake to Ursus Islands, a breeding range extension of ca. 250 km northeast. Early arrival dates 10 June 1978 and 17 June 1989.

GREEN-WINGED TEAL (*Anas crecca*). Uncommon CB. Seen near Grassy Island (Clarke 1940; Norment 1985). Five records of females with flightless young 1973 to 1991, from Eyeberry Lake north to Lookout Point; extends breeding range 300 km north.

KING EIDER (*Somateria spectabilis*). Rare vagrant. A single record, that of a lone male 30 km north of Hornby Point, 7 July 1987. Not recorded by Clarke (1940) in TWS.

HARLEQUIN DUCK (*Histrionicus histrionicus*). Rare vagrant. One record, of two males at Damant Lake, 200 km south of the TWS, 20 June 1973. Breeds near Yellowknife (Bromley and Trauger 1981), but no published records for areas east of Great Slave Lake.

SURF SCOTER (*Melanitta perspicillata*). Uncommon CB. Frequently seen north along Thelon River as far as Ursus Islands, both in conspecific flocks and with Black Scoters (*M. nigra*). Four breeding records for area: a female with young on Elk River near its junction with Thelon (17 August 1992), and females with young 25 km southeast of where Thelon River leaves Lynx Lake (12 August 1990, 15 August 1993, and 15 August 1994), a northeastward breeding range extension of ca. 150 km (Godfrey 1986). Clarke (1940) did not observe Surf Scoters in the TWS.

WHITE-WINGED SCOTER (*Melanitta fusca*). Occasional vagrant. No evidence that species breeds in TWS, although sometimes seen in flocks along Thelon River and its tributaries during summer (Norment 1985). Clarke (1940) did not observe this species in the TWS.

BLACK SCOTER (*Melanitta nigra*). Uncommon vagrant. No evidence that species breeds in TWS area, although sometimes seen in flocks along Thelon River and its tributaries during summer (Norment 1985). Clarke (1940) did not observe this species in the TWS.

BUFFLEHEAD (*Bucephala albeola*). Rare vagrant. A lone female or sub-adult observed near WG, 26 June 1991. Not recorded previously in TWS (Clarke 1940).

COMMON GOLDENEYE (*Bucephala clangula*). Rare vagrant. Norment (1985) recorded one bird in the TWS in 1978. We have four additional records; three flocks of eight birds each in June 1991 at WG, and one of two males, 12 July 1987 at Ursus Islands. Wanders north of breeding range in summer (Godfrey 1986); not recorded by Clarke (1940).

COMMON MERGANSER (*Mergus merganser*). Uncommon CB. Seen regularly along Thelon River as far north as Ursus Islands, but only one breeding record: a female with flightless young at Grassy Island, 3 August 1991. Common Mergansers seen previously in TWS (Clarke 1940; Norment 1985), but this is the first breeding record for area, and a northeastward breeding range extension of ca. 200 km.

OSPREY (*Pandion haliaetus*). Rare vagrant. Two records in Thelon River Valley, both near Eyeberry Lake, about 40 km south of TWS (25 July 1981, and 29 July 1991), and ca. 350 km northeast of breeding range in Godfrey (1986). However, nest with three eggs found near Coventry Lake on Upper Taltson River, 11 June 1977 (AH), ca. 100 km north of breeding range in Godfrey (1986).

BALD EAGLE (*Haliaeetus leucocephalus*). Uncommon CB; observed to northern limit of spruce, west of Beverly Lake. A pair observed almost every year since 1978 near Hornby Point, and a newly fledged eaglet was seen with two adults 3 km below Hornby Point, 6 August 1991. An adult was also seen on a stick nest in a spruce along Clarke River, 50 km east of junction with Thelon River, 27 June 1988. Previously observed in TWS (Kuyt 1980), but breeding range in Godfrey (1986) ca. 225 km southwest of Hornby Point. Not recorded by Clarke (1940).

NORTHERN HARRIER (*Circus cyaneus*). Uncommon PO. Observed at WG at least four times per year 1989 to 1991, including a pair hunting together, 7 June 1991. Sightings at Grassy Island in 1984, 1986, and 1987, plus three additional records downstream to Ursus Islands, suggest that species breeds in TWS. Godfrey (1986) shows northern limit of the breeding range ca. 225 km southwest of Grassy Island. Not seen by Clarke (1940).

NORTHERN GOSHAWK (*Accipiter gentilis*). Rare vagrant. One observed at WG, 3 June 1991. Recorded in fall and summer (Norment 1985), but first spring record for TWS. Not recorded by Clarke (1940).

GOLDEN EAGLE (*Aquila chrysaetos*). Rare CB. Adult and two nearly fledged young observed at stick nest on cliffs at "The Gap," just south of Grassy Island, 3

August 1991. Previously recorded in TWS (Kuyt 1980), although not seen by Clarke (1940). Godfrey (1986) included TWS in breeding range, but this is the first published breeding record for area. Bald Eagles more frequent than Golden Eagles along Thelon River upstream from Ursus Islands, while latter species more common downstream.

AMERICAN KESTREL (*Falco sparverius*). Rare CB. Two breeding records from Thelon River Valley: a pair of adults with newly fledged young near Lynx Lake on Elk River, 11 August 1980, and a pair defending a nest 45 km north of Hornby Point, 2 August 1987. Latter record is a northeastward breeding range extension of 400 km (Godfrey 1986). Not recorded by Clarke (1940).

MERLIN (*Falco columbarius*). Rare CB. Clarke (1940) did not record the species in TWS, but Kuyt (1980) reported one nest from near Lookout Point. A second nest found in a White Spruce 15 km north of Grassy Island on 4 July 1993, and lone birds or pairs seen at WG in 1978, 1989, 1990, and 1991. Early arrival dates 26 May 1978 and 30 May 1989.

GYRFALCON (*Falco rusticolus*). Uncommon CB. Although neither Clarke (1940) nor Critchell-Bullock (1931) observed species along the Hanbury and Thelon rivers, Gyrfalcons have bred in the Thelon River valley at least since 1961 (Kuyt 1962c, 1980; Norment 1985).

SANDHILL CRANE (*Grus canadensis*). Uncommon CB. Although Godfrey (1986) included TWS in breeding range, and species is often seen along Thelon River (Clarke 1940; Mowat and Lawrie 1955; Norment 1985), a flightless chick photographed on 13 July 1993 3 km west of Beverly Lake apparently is first confirmed breeding record for TWS.

LESSER YELLOWLEGS (*Tringa flavipes*). Locally common PB in areas such as marshes at mouth of Finnie River and near Steel Lake, 5 km northwest of WG. Found along Thelon River as far as 30 km north of Lookout Point, and along Clarke and lower Hanbury rivers (Clarke 1940; AH and CJN, personal observation). Although we have not seen nests or young, we have frequently noted individuals displaying alarm behavior (scolding, flying near intruders) during breeding season. Clarke (1940) observed species along Thelon River, but noted no evidence of breeding. Breeding range extends to treeline at Artillery Lake, 160 km southwest of TWS (Godfrey 1986).

WHIMBREL (*Numenius phaeopus*). Rare vagrant. One record of three at Ursus Islands, 10 July 1984. Not recorded by Clarke (1940).

LEAST SANDPIPER (*Calidris minutilla*). Common CB. Seven nests found near WG 1989 to 1991 represent first confirmed breeding records for TWS.

PARASITIC JAEGER (*Stercorarius parasiticus*). Common CB in tundra habitats. As with the Long-tailed Jaeger, Clarke (1940) observed the species along Thelon River, and Godfrey (1986) showed breeding range as including TWS. However, there apparently are no published breeding records for TWS. On 9 July 1993, a nest with one chick was found near Lookout Point.

LONG-TAILED JAEGER (*Stercorarius longicaudus*). Common CB in tundra habitats. No published breeding records for TWS, but a nest with nestlings was located in TWS, 13 July 1993, 3 km west of Beverly Lake. Known breeding range extends south to near southern boundary of TWS (Godfrey 1986); however, we have a nest record for the species at Rennie Lake on Elk River, a southerly range extension of 210 km.

BONAPARTE'S GULL (*Larus philadelphia*). Uncommon CB. Observed along Thelon River drainage from Elk River north to Lookout Point. A group of Bonaparte's Gulls with young almost to flying stage observed 29 July 1996, 8 km north of Hornby Point. On 14 July 1997, three nests were seen near a small pond in vicinity of 1996 sighting. Extends breeding range ca. 300 km northeast of range in Godfrey (1986). Not seen by Clarke (1940).

MEW GULL (*Larus canus*). Uncommon CB. Found along Thelon River between Hanbury/Thelon junction and Beverly Lake; a pair seen at a nest with one egg on 8 June 1989 near Steel Lake. Godfrey (1986) describes the Mew Gull as "perhaps" breeding in the "Thelon River marshes," but this record extends known breeding range ca. 160 km northeast of range in Godfrey (1986).

RING-BILLED GULL (*Larus delawarensis*). Vagrant. Lone individual seen near WG, 7 June 1991. Not recorded previously in TWS.

GLAUCOUS GULL (*Larus hyperboreus*). Occasional migrant. Noted at WG on 29 May 1989, 15 June 1990, 3 June 1991, and 5 June 1991. Not recorded previously in TWS.

SHORT-EARED OWL (*Asio flammeus*). Rare CB (Norment 1985). Short-eared Owls observed at WG in 1978 (five records), 1989 (two records), and 1991 (two records), and at Grassy Island in 1978 (one record). Nest with two newly hatched young and two eggs found 10 km west of Lookout Point, 12 July 1978. Early observation date 28 May in 1978 and 1989.

EASTERN KINGBIRD (*Tyrannus tyrannus*). Rare vagrant. A lone individual was seen on 3 June and 25 June 1989 at WG. The 3 June bird was captured in a mist net and photographed. Not observed by Clarke (1940), but has wandered north to Bathurst Inlet (Snyder 1957). The nearest breeding record is ca. 450 km to the southwest (Godfrey 1986).

NORTHERN SHRIKE (*Lanius excubitor*). Occasional CB. Although Clarke (1940) did not record Northern Shrikes in TWS, they bred near WG in 1978 (Norment 1985). Repeated observation of birds at WG in 1989 and 1990, and presence of a nest with five eggs in 1991, suggest that species is a regular breeder in area. Early arrival date at WG 6 May 1978.

HOUSE WREN (*Troglodytes aedon*). Vagrant. A lone bird was observed singing in a spruce stand near WG, 21 June 1978. Not observed by Clarke (1940). The nearest breeding record is ca. 600 km to the southwest (Godfrey 1986).

GRAY-CHEEKED THRUSH (*Catharus minimus*). Common CB. Although common along the Thelon River in the 1930s (Clarke 1940), six nests found at WG in 1978 and 1989–1991 represent the first published records for TWS.

VARIED THRUSH (*Ixoreus naevius*). Vagrant. Two females foraging on tundra near WG, 27 May 1991. Not observed by Clarke (1940).

BROWN THRASHER (*Toxostoma rufum*). Vagrant. A weakened individual was observed at WG on 27 May 1989. Not observed by Clarke (1940). This individual was ca. 1000 km north of the breeding range in Godfrey (1986).

ORANGE-CROWNED WARBLER (*Vermivora celata*). Vagrant. A lone individual was seen foraging in willows (*Salix* spp.) near Steel Lake, 9 June 1990. Not observed by Clarke (1940).

YELLOW WARBLER (*Dendroica petechia*). Rare PO. Three records for the TWS; on 13 June 1991 at Steel Lake, and singing males on 17 July 1991 and 25 July 1996, both near junction of Clarke and Thelon rivers. Although Godfrey (1986) shows the breeding range as extending north of treeline in the western Mackenzie, no previous records for TWS (Clarke 1940; Norment 1985).

YELLOW-RUMPED WARBLER (*Dendroica coronata*). Uncommon CB. Godfrey (1986) indicates that the species breeds "near the junction of the Hanbury and Thelon rivers," but there are no confirmed records of breeding in TWS. Territorial, paired Yellow-rumped Warblers were found in spruce near WG in 1978, 1989, 1990, and 1991, and an adult was seen carrying food on 6 July 1988 at Hornby Point. Although not observed by Clarke (1940), we found the species along Thelon River as far as Lookout Point. Early arrival dates at WG 28 May 1991 and 30 May 1990.

BLACKPOLL WARBLER (*Dendroica striata*). Common CB. Known breeding range includes TWS (Godfrey 1986), and encountered frequently along Thelon River by Clarke (1940), but a nest with four eggs at WG on 22 June 1989 first published breeding record for TWS.

NORTHERN WATERTHRUSH (*Seiurus noveboracensis*). Vagrant. A male waterthrush was seen at WG, 7 June 1991. Not observed by Clarke (1940).

WILSON'S WARBLER (*Wilsonia pusilla*). Vagrant (PO?). A singing male seen foraging in willows near Steel Lake, 13 June 1991. Breeds to treeline at Artillery Lake, ca. 160 km southwest of TWS (Godfrey 1986). Not observed by Clarke (1940).

SMITH'S LONGSPUR (*Calcarius pictus*). Uncommon PO. Although species breeds in forest-tundra throughout Canada (Godfrey 1986), we are not aware of published records for TWS (Clarke 1940; Norment 1985). Paired, singing males seen on several occasions in open spruce woodland 3 km southeast of WG in 1989 and 1991.

RUSTY BLACKBIRD (*Euphagus carolinus*). Locally common CB. Bred at Grassy Island and near Lookout Point in 1978, where over 30 birds with young were seen (Norment 1985). Presence of migrants at WG in 1989–1991, and breeding birds at Steel Lake in 1989–1991, indicates that species widely established in suitable habitat along middle Thelon River downriver to Ursus Islands. Also common in upper Thelon watershed. Not recorded by Clarke (1940). Early dates at WG 21 May 1978 and 28 May 1989 and 1990.

Mammals

RED SQUIRREL (*Tamiasciurus hudsonicus*). Not found at WG, or anywhere in area between Hanbury/Thelon junction and Beverly Lake, in 1977–1978. However, Red Squirrels present in at least five spruce stands within 5-km radius of WG in 1989–1991. In 1997, Red Squirrels common between Grassy Island and a point 5 km upstream from Hornby Point. A lone squirrel also seen on 1 July 1997 along Clarke River, 65 km upstream from its junction with Thelon River. Banfield (1974) showed the range as extending to just northeast of Great Slave Lake. Clarke (1940) noted species at Artillery Lake, but did not find any squirrels along Thelon River in 1936 and 1937. Visitors to the Thelon River area in the 1920s made no mention of Red Squirrels (Critchell-Bullock 1931; Christian 1937).

BEAVER (*Castor canadensis*). Clarke (1940) did not report Beavers along Thelon River, although Kuyt (1965a) saw one near Hornby Point in 1965. An active lodge at Grassy Island in 1977 and 1978, and a single Beaver seen between Hornby Point and Lookout Point on 1 August 1986. Fresh cuttings along the Thelon River in the TWS in late 1970s and 1980s, but not after 1989, suggest that Beaver were present in TWS during 1970s and 1980s, but have since died out.

PORCUPINE (*Erethizon dorsatum*). Clarke (1940) did not report Porcupines beyond Great Slave Lake, and Banfield (1974) showed range as extending north to treeline in region. Kuyt (1965b) reported Porcupine sign at WG and below Grassy Island. Porcupines not present at WG in 1977–1978 or 1989–1991, but AH observed fresh sign between Grassy Island and Lookout Point from 1987 onwards, and a lone individual on 5 July 1989, 32 km upriver from Lookout Point.

RIVER OTTER (*Lutra canadensis*). Although Clarke (1940) listed several records north of treeline, Banfield (1974) showed range extending only to treeline in vicinity of Great Slave Lake. We have eight sightings along lower Elk River near Thelon River in August 1992 and five records of otters from Thelon River: fresh tracks at Eyeberry Lake (21 July 1988); scat below Grassy Island (26 July 1988); one otter above Hornby Point (27 July 1988); tracks near Thelon-Mary Frances junction (10 July 1994); and tracks at south end of Eyeberry Lake (28 July 1997).

MOOSE (*Alces alces*). In 1977–1978, Moose were observed along Thelon River between WG and Lookout Point, and were most common at Grassy Island. Forty-four Moose (including 15 yearlings) counted during helicopter survey from WG to a point 25 km northeast of Hornby Point on 12 March 1978. Adult bulls, cows, and yearlings also seen near WG in 1989–1991; AH observed Moose on numerous occasions between WG and Lookout Point in 1977–1997. Although Back (1836) mentioned reports of Moose along the Thelon River, and Hanbury (1904) and Tyrrell (1902) reported seeing Moose sign in the Thelon River Valley, Kelsall (1972) questioned these accounts, and Moose were very rare in the area at the turn of the century. Moose were not present along Thelon River in 1936–1937 (Clarke 1940), and were not seen by the Hornby party in 1926–1927 (Christian 1937). Solitary bull Moose or sign were occasionally seen in TWS during 1950s and 1960s (Kuyt 1965a, b; Kelsall 1972), and AH saw one bull Moose near Lookout Point, and signs of others, in 1974. However, no evidence of successful reproduction in the TWS until 1977–1978, and it appears that a large increase in Moose numbers in the TWS occurred between 1974 and 1977.

Discussion

We present information on the status of 50 bird species in the Thelon River Valley. Included in this total are nine confirmed breeding records for species not previously reported breeding north of treeline (Mallard, Green-winged Teal, American Widgeon, Surf Scoter, Common Merganser, Bald Eagle, American Kestrel, Mew Gull, and Bonaparte's Gull), and three southward range extensions for tundra-breeding species (Tundra Swan, Greater White-fronted Goose, and Long-tailed Jaeger). We add 24 species (confirmed, probable, or possible) to the list of breeding birds for the TWS. Many of these species, such as the Mallard, Green-winged Teal, American Widgeon, Mew Gull, and Yellow-rumped Warbler, have been noted previously in the TWS (Clarke 1940; Kuyt 1980; Norment 1985), but are outside of their documented breeding range in Godfrey (1986). The breeding range of other species (Sandhill Crane, Long-tailed Jaeger, Parasitic Jaeger, Short-eared Owl, Gray-cheeked Thrush, Blackpoll Warbler) includes the Thelon River (Godfrey 1986), although documented breeding records were previously lacking for the TWS. We also add 16 species not previously recorded in the TWS. Most of these are spring vagrants, although one species breeds in the sanctuary (American Kestrel) and three others possibly breed there (Yellow Warbler, Wilson's Warbler, and Smith's Longspur).

Thirty bird species described here, along with Red Squirrel, Beaver, Porcupine, River Otter, and Moose, were not observed along the Hanbury and Thelon rivers by either Critchell-Bullock (1931) in 1925 or by Clarke (1940) in 1936–1937; nine additional confirmed breeding species (Green-winged Teal, Common Merganser, Sandhill Crane, Lesser Yellowlegs, Parasitic and Long-Tailed Jaegers, Mew Gull, Gray-cheeked Thrush, and Blackpoll Warbler) were noted by Clarke (1940), but without evidence of breeding. There are several hypotheses for these apparent changes in the fauna of the Thelon River Valley (cf. Kessel and Gibson 1994). First, Clarke and Critchell-Bullock may have missed many species that were present in low numbers in the 1920s and 1930s; our additions are from increased search effort over a 25-year period. Second, our observations could have detected species that moved into the Thelon River Valley for the first time, as either breeding species, migrants, or vagrants, within the last 40–60 years. Third, the changes could represent natural, long-term fluctuations in species numbers and/or distributions at the margins of their ranges. Finally, some additions (or species that were missed earlier) could be due to confused identifications by either Clarke or ourselves. Distinguishing between these hypotheses may be difficult (Kessel and Gibson 1994) because hypotheses two and three are not mutually exclusive, and because detecting faunal turnover (either colonization or extinction) requires extensive, standardized surveys over time (Lynch and Johnson 1974).

Many of the 30 species not observed by Clarke (1940) and Critchell-Bullock (1931) are either vagrants or spring migrants (n = 15; e.g., Common Goldeneye, Bufflehead, Brown Thrasher, Northern Waterthrush), or apparently breed irregularly or at scattered locations in the TWS (n = 11; e.g., Surf

Scoter, Bald Eagle, American Kestrel, Merlin, Bonaparte's Gull, Northern Shrike). Included in the "irregular breeder" category are three species for which evidence of breeding is based only on the presence of singing and/or paired males, and is thus equivocal (Yellow Warbler, Wilson's Warbler, and Smith's Longspur). Four species are relatively common and widespread breeders (Mallard, American Widgeon, Yellow-rumped Warbler, and Rusty Blackbird). These totals can be compared to those in a previous paper on TWS birds, which reported records gathered primarily at WG between August 1977 and July 1978 (Norment 1985). Of 25 species not seen by Clarke or Critchell-Bullock but reported by Norment (1985), eight were migrants, five were vagrants, six were relatively widespread species which breed in the TWS (Mallard, American Widgeon, Surf Scoter, Gyrfalcon [Kuyt 1962c, 1980]; Yellow-rumped Warbler, and Rusty Blackbird [Norment 1985]), and six were uncommon species which breed or probably breed in the TWS, but with restricted distributions (Bald Eagle, Northern Harrier, Golden Eagle, Merlin, Bonaparte's Gull, Short-eared Owl, Northern Shrike).

Many records for the Thelon River Valley accumulated since the 1930s are most easily explained by increased search effort in recent years, and the absence of Clarke (1940) and Critchell-Bullock (1931) from the Thelon River Valley during the spring and fall migration periods. Thus, all new vagrants and spring migrants, and many less common breeding species, could have been missed by Clarke or Critchell-Bullock. A similar explanation has been advanced for the discovery of unusual breeding localities in Alaska (Sage 1973; Bailey 1975) and could apply to range extensions such as that of the American Tree Sparrow (*Spizella arborea*) in northern Quebec (Weatherhead and Bider 1980). However, it is likely that six relatively common and easily identified species have colonized the middle Thelon River area since the 1930s: Mallard, American Widgeon, Surf Scoter, Gyrfalcon, Yellow-rumped Warbler, and Rusty Blackbird. Although we are uncertain about the historical status of uncommon or rare breeding species, we also suspect that the Common Loon, Bald Eagle, Merlin, Northern Harrier, Bonaparte's Gull, and Northern Shrike did not breed along the middle Thelon River during the time of Critchell-Bullock's and Clarke's visits. Our reasoning regarding the six former species is as follows.

First, C. H. D. Clarke was an excellent naturalist and probably would have missed few, if any, common species. In 1937 Clarke spent two months canoeing the Hanbury and Thelon rivers to Baker Lake, including 20 days between the lower Hanbury River and Beverly Lake. He camped near WG for five days, and spent two days each at both Grassy Island and the mouth of the Finnie River (C. H. D. Clarke, unpublished field notes). It is thus unlikely that he would have missed easily detected species that are now relatively common at WG, Grassy Island, the mouth of the Finnie River, or along the Thelon River if they were present. For example, he would have passed at least four Gyrfalcon aeries along the Hanbury and Thelon Rivers that were active in the 1960s and 1970s (Kuyt 1962c and 1980; CJN, unpublished records). Clarke once argued to AH that he could not have missed Gyrfalcons during his 1937 trip if the species had been present. However, Gyrfalcons nest early along the Thelon River (Kuyt 1980), and they could have abandoned failed nests if primary prey species such as ptarmigan (*Lagopus* spp.) were uncommon in 1937 (Robert Bromley, personal communication). Although Critchell-Bullock (1931) traveled the Hanbury and Thelon rivers under very adverse conditions (Whalley 1962), the fact that he did not observe Mallard, American Widgeon, Surf Scoter, Gyrfalcon, Yellow-rumped Warbler, and Rusty Blackbird corroborates Clarke's observations. Also, other naturalists who visited areas north of treeline to the east of the TWS along the Dubawnt and Kazan rivers in the 1930s, 1940s and 1950s also reported that Mallard, American Widgeon, Surf Scoter, Gyrfalcon, Yellow- rumped Warbler, and Rusty Blackbird were absent or extremely rare (Porsild in Manning 1948; Manning 1948; Harper 1953; Mowat and Lawrie 1955). These authors also did not report Bald Eagle, Merlin, Northern Harrier, Bonaparte's Gull, and Northern Shrike, which is consistent with the hypothesis that these species have only recently colonized areas north of treeline.

Although Kelsall (1972) hypothesized that the increase in Moose observations at treeline and on the tundra may have been due in part to increased human travel, it is unlikely that Clarke (1940) would have missed Moose, Beaver, or Red Squirrels during his exploration of the Thelon River Valley. The Hornby party, which hunted extensively between Grassy Island and Hornby Point, did not encounter these species (Christian 1937), and Moose were rarely seen north of treeline in the Nueltin Lake area through the early 1950s (Harper 1956). Kelsall (1972) found few authenticated sightings of Moose from the TWS through the 1960s, although Kuyt (1965a, b) reported some Moose sign from the Lookout Point area in the early 1960s.

A major factor that may have allowed for the colonization of the middle Thelon River area by a number of bird and mammal species could be climate change in the forest-tundra. Johnson (1994) has proposed a similar explanation for the enlargement of the breeding ranges of 24 bird species in the western United States, with increased summer moisture and perhaps higher mean temperatures interacting in both the northward expansion of southwestern species and the southward expansion of northern species. Coincident with changes in the distribution of western birds has been the northward movement of 19 mammal species in the southwest United States (Davis and Callahan 1992). Analysis of Northern Hemisphere records indicate positive trends in Arctic and larger-scale annual temperatures (Jones et al. 1986; Hansen and Lebedeff 1987; Chapman and Walsh 1993) over the last century, with the recent warming trend being strongest during winter and spring (Chapman and Walsh 1993). This trend is corroborated by tree ring-width and maximum latewood density time series from the northern treeline (D'Arrigo et al 1991; D'Arrigo et al. 1996) in Canada. Interpretation of maximum latewood density data, which include a series from Hornby Point, suggest warmer summer temperatures in the 1970s and 1980s following cooler summers during the 1950s and 1960s (D'Arrigo et al. 1991). Interpretation of the Hornby Point density data is somewhat difficult because White Spruce tree ring widths in the area have declined during the same time period when the spruce density chronology and a Larch (*Larix laricina*) chronology show opposite trends (D'Arrigo et al. 1991; Gordon Jacoby, personal communication). However, similar differences in ring width and density measurements from White Spruce at the Alaskan treeline have been attributed to moisture stress induced by a combination of warmer and drier years (Jacoby and D'Arrigo 1995).

Climate warming has also been invoked as an explanation for apparent changes in the avifauna of the Lake Athabasca region in northern Saskatchewan (Nero 1963, 1967). In 1960, 1961, and 1962, Nero (1963) recorded 14 bird species along the north shore of Lake Athabasca not observed by Francis Harper during extensive fieldwork in 1914 and 1920. While some species may have been overlooked by Harper, it is unlikely that he would have missed Red-winged Blackbirds (*Agelaius phoeniceus*), Palm Warblers (*Dendroica palmarum*), or White-throated Sparrows (*Zonotrichia albicollis*), all of which were recorded as "common" by Nero (1963). Harper (1961) attributed apparent advances of boreal or temperate-breeding species into the Lake Athabasca region, as well as changes in the distribution of avifauna on the Ungava Peninsula, to a warming of summer temperatures since 1900.

Warmer summer temperatures would benefit boreal bird species colonizing the Thelon Valley by providing more moderate breeding conditions in an environment where severe inclement weather during May and June can delay breeding or cause high mortality among breeding species (Norment 1985, 1992). In contrast, moderating conditions during the fall, winter and early spring may have allowed non-migratory Red Squirrels, Porcupines and Moose to colonize the area. Combinations of extreme cold and wind limit Moose in some areas (Miller et al. 1972), although snow thickness is more often limiting (Nasimovitch 1955; Kelsall and Telfer 1974; Bishop and Rausch 1974). There are no long-term data on snow thickness in the Thelon River area, although snow accumulation in 1977–1978 was never sufficient to cover most willow stands at Grassy Island (CJN, personal observation). Moose populations also increased in northern portions of Alaska in the 1950s and 1960s (Coady 1980), and recent evidence suggests northward range expansion of Moose to treeline in Labrador (Chubbs and Schaefer 1997).

Although apparent changes in the avian and mammalian fauna of the Thelon River valley are consistent with an hypothesis linked to climate change, as Rodenhouse (1997) has pointed out, "observations or censuses combined with climatic data are simply inadequate to link climate causally with changes in bird distribution." An alternative hypothesis for the recent (post 1930s) colonization of the Thelon River area by some birds and mammal species is that these events are due to increasing populations in more southerly areas and the spread of surplus individuals into previously uncolonized habitat. This hypothesis is difficult to evaluate because there are no accurate records for waterfowl numbers prior to 1955, when standardized spring waterfowl counts began in the northern United States, Canada, and Alaska (Bellrose 1976), or for breeding passerines prior to the initiation of the North American Breeding Bird Survey (Robbins et al. 1986). In addition, spread of surplus individuals from more southerly areas could have been facilitated by moderating climatic conditions.

Whatever the cause of apparent changes in the bird and mammal fauna of the Thelon River area since the 1930s, increased interest in the biota of the forest-tundra zone as indicators of environmental change due to possible global warming (Zoltai 1988; D'Arrigo et al. 1991; Timoney et al. 1992) suggest that it is important to begin long-term monitoring of bird and mammal populations in the region. Given the protected status of the TWS and its relatively diverse biota, and the extensive mineral exploration that is occurring in other parts of the NWT, such a monitoring program might be best undertaken in the Thelon River valley.

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Literature Cited

Alexander, S. A., R. S. Ferguson, and **K. J. McCormick.** 1991. Key migratory bird terrestrial habitat sites in the Northwest Territories. Occasional Paper 71, Canadian Wildlife Service, Ottawa, Ontario.

American Ornithologists' Union. 1998. The A. O. U. checklist of North American birds. 7th edition. American Ornithologists' Union, Washington, D. C.

Back, G. 1836. Narrative of the arctic land expedition to the mouth of the Great Fish River. John Murray, London, U. K.

Bailey, E. P. 1975. Discovery of Golden Eagle nest on the Alaska Peninsula. Condor 77: 207–208.

Banfield, A. W. F. 1974. The mammals of Canada. National Museums of Canada and University of Toronto Press, Toronto, Ontario.

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. 2nd edition. Stackpole Books, Harrisburg, Pennsylvania.

Bird, J. B. 1951. The physiography of the middle and lower Thelon Basin. Geographical Bulletin 1: 14–19.

Bishop, R. H., and **R. A. Rausch.** 1974. Moose population fluctuations in Alaska 1950–1972. Le Naturaliste canadien 101: 559–571.

Bromley, R. G., and **D. L. Trauger.** 1981. Birds of Yellowknife: A regional checklist. Ecology North, Yellowknife, Northwest Territories.

CACNMP [Conservation Advisory Committee on the Northern Mineral Policy]. 1990. Thelon Game Sanctuary report. Indian and Northern Affairs Canada, Ottawa, Ontario.

Chapman, W. L., and **J. E. Walsh.** 1993. Recent variations of sea ice and air temperatures in high latitudes. Bulletin American Meteorological Society 74: 33–47.

Christian, E. V. 1937. Unflinching: A diary of tragic adventure. John Murray, London, U. K.

Chubbs, T. E., and **J. A. Schaefer.** 1997. Population growth of Moose, *Alces alces*, in Labrador. Canadian Field-Naturalist 111: 238–242.

Clarke, C. H. D. 1940. A biological investigation of the Thelon Game Sanctuary. National Museum of Canada Bulletin 96. 135 pages.

Clayton, J. S., W. A. Erlich, D. B. Cann, J. H. Day, and **I. B. Marshall.** 1977. Soils of Canada. Volume 1. Soil report. Agriculture Canada. Ottawa. 243 pages.

Coady, J. W. 1980. History of Moose in northern Alaska and adjacent regions. Canadian Field-Naturalist 94: 61–68.

Critchell-Bullock, J. C. 1931. An expedition to sub-arctic Canada. Canadian Field-Naturalist 45: 11–18.

D'Arrigo, R. D., G. C. Jacoby, and **R. M. Free.** 1991. Tree-ring and maximum latewood density at the North American tree line: Parameters of climatic change. Canadian Journal of Forest Research 22: 1290–1296.

D'Arrigo, R. D., E. R. Cook, and **G. C. Jacoby.** 1996. Annual to decadal-scale variations in northwest Atlantic sector temperatures inferred from Labrador tree rings. Canadian Journal of Forest Research 26: 143–148.

Davis, R., and **J. R. Callahan.** 1992. Post-Pleistocene dispersal in the Mexican vole (*Microtus mexicanus*): an example of an apparent trend in the distribution of southwestern mammals. Great Basin Naturalist 52: 262–268.

Godfrey, W. E. 1986. The birds of Canada. 2nd edition. National Museum of Natural Sciences, Ottawa, Ontario.

Hanbury, D. 1904. Sport and travel in the northland of Canada. Edward Arnold, London, U.K.

Hansen, J., and **S. Lebedeff.** 1987. Global trends of measured surface air temperature. Journal Geophysical Research 92: 12 372–13 345.

Harper, F. 1953. The birds of the Nueltin Lake Expedition. American Midland Naturalist 49: 1–116.

Harper, F. 1956. The mammals of the Keewatin. University of Kansas Museum of Natural History Special Publication 12: 1–94.

Harper, F. 1961. Changes in climate, faunal distribution, and life zones in the Ungava Peninsula. Occasional Publications of the Steffansson Collection 3: 20–41.

Jacoby, G. C., and **R. D'Arrigo.** 1995. Tree ring width and density evidence of climatic and potential forest change in Alaska. Global Biogeochemical Cycles 9: 227–234.

Jehl, J. R., Jr., and **B. A. Smith.** 1970. Birds of the Churchill Region, Manitoba. Special Publication Number 1, Manitoba Museum of Man and Nature, Winnipeg, Manitoba.

Johnson, N. K. 1994. Pioneering and natural expansion of breeding distributions in western North American birds. Studies in Avian Biology 15: 27–44.

Jones, P. D., T. M. L. Wrigley, and **P. B. Wright.** 1986. Global temperature variations between 1861 and 1984. Nature 322: 430–434.

Kelsall, J. P. 1972. The northern limits of moose (*Alces alces*) in western Canada. Journal of Mammalogy 53: 129–138.

Kelsall, J. P., and **E. S. Telfer.** 1974. Biogeography of moose with special reference to western North America. Le Naturaliste canadien 101: 117–130.

Kessel, B., and **D. D. Gibson.** 1994. A century of avifaunal change in Alaska. Studies in Avian Biology 15: 4–13.

Kuyt, E. 1962a. White-fronted Geese breeding in the Thelon Valley, N.W.T. Canadian Field-Naturalist 76: 224.

Kuyt, E. 1962b. Northward dispersion of banded Canada Geese. Canadian Field-Naturalist 76: 180–181.

Kuyt, E. 1962c. A record of a tree-nesting Gyrfalcon. Condor 64: 508–510.

Kuyt, E. 1965a. Additional notes on recent occurrence of mammals in the Thelon Game Sanctuary, N.W.T. Blue Jay 23: 174.

Kuyt, E. 1965b. Three mammal records from the Thelon Game Sanctuary, N.W.T. Blue Jay 23: 134–135.

Kuyt, E. 1966. Further observations on large Canada Geese moulting on the Thelon River, Northwest Territories. Canadian Field-Naturalist 80: 63–69.

Kuyt, E. 1980. Distribution and breeding biology of raptors in the Thelon River area, Northwest Territories, 1957–1969. Canadian Field-Naturalist 94: 121–130.

Larsen, J. A. 1965. The vegetation of the Ennadai Lake area, N.W.T.: Studies in subarctic and arctic bioclimatology. Ecological Monographs 35: 37–59.

Lynch, J. F., and **N. K. Johnson.** 1974. Turnover and equilibria in insular avifaunas, with special reference to the California Channel Islands. Condor 76: 370–384.

Manning, T. H. 1948. Notes on the country, birds, and mammals west of Hudson Bay between Reindeer and Baker lakes. Canadian Field-Naturalist 62: 1–28.

McLaren, M. A., and **P. L. McLaren.** 1981. Relative abundances of birds in boreal and subarctic habitats of northwestern Ontario and northeastern Manitoba. Canadian Field-Naturalist 95: 418–427.

Miller, F. L. E., E. Broughton, and **E. M. Land.** 1972. Moose fatality resulting from overextension of range. Journal of Wildlife Disease 8: 95–98.

Mowat, F. M., and **A. H. Lawrie.** 1955. Bird observations from southern Keewatin and the Interior of northern Manitoba. Canadian Field-Naturalist 69: 38–47.

Nasimovitch, A. A. 1955. The role of the regime of snow cover in the life of ungulates in the U.S.S.R. (Akademiya Nauk S.S.R., Moskva). Translated from Russian, Canadian Wildlife Service, Ottawa, Ontario. 371 pages.

Nero, R. W. 1963. Birds of the Lake Athabasca Region, Saskatchewan. Special Publications of the Saskatchewan Natural History Society 5: 1–143.

Nero, R. W. 1967. The birds of northern Saskatchewan. Special Publications of the Saskatchewan Natural History Society 6: 1–92.

Nettleship, D. N., and **P. A. Smith.** 1975. Ecological sites in northern Canada. Canadian Committee for the International Biological Programme. Ottawa, Ontario.

NORAC [The North American Ornithological Atlas Committee]. 1990. Handbook for atlasing American breeding birds. Vermont Institute of Natural Science, Woodstock, Vermont.

Norment, C. J. 1985. Observations on the annual chronology for birds in the Warden's Grove area, Thelon River, Northwest Territories, 1977–1978. Canadian Field-Naturalist 99: 471–483.

Norment, C. J. 1992. Comparative breeding biology of Harris' Sparrows and Gambel's White-crowned Sparrows in the Northwest Territories, Canada. Condor 94: 955–975.

Porsild, A. E. 1943. Birds of the Mackenzie Delta. Canadian-Field Naturalist 57: 19–35.

Robbins, C. S., D. Bystrak, and **P. H. Geisler.** 1986. The breeding birds survey: Its first fifteen years, 1966–1979. United States Fish and Wildlife Service Resource Publication 157. Washington D.C.

Rodenhouse, N. L. 1997. [Book Review]. Birds and climate change. Condor 99: 242–243.

Sage, B. L. 1973. Cliff Swallow colony in arctic Alaska. Condor 75: 356.

Snyder, L. L. 1957. Arctic birds of Canada. University of Toronto Press, Toronto, Ontario.

Timoney, K. P., G. H. La Roi, S. C. Zoltai, and **A. L. Robinson.** 1992. The high sub-arctic forest-tundra of Northwestern Canada: Position, width, and vegetation gradients in relation to climate. Arctic 45: 1–9.

Tyrrell, J. W. 1902. Exploratory survey between Great Slave Lake and Hudson Bay, Districts of Mackenzie and Keewatin. Annual Report of the Department of the Interior, Sessional Paper Number 25, Appendix Number 25, pages 98–155, 207–329.

Weatherhead, P. J., and **J. R. Bider.** 1980. Avian range extension northward to Deception Bay, Quebec. Arctic 33: 369.

Whalley, G. 1962. The legend of John Hornby. John Murray, London, U. K.

Zoltai, S. C. 1988. Ecoclimatic provinces of Canada and man-induced climatic change. Canada Committee on Ecological Land Classification Newsletter 17: 12–15.

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Activity Patterns of American Martens, *Martes americana*, Snowshoe Hares, *Lepus americanus*, and Red Squirrels, *Tamiasciurus hudsonicus*, in Westcentral Montana

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Foresman, Kerry R., and D. E. Pearson. 1999. Activity patterns of American Martens, *Martes americana*, Snowshoe Hares, *Lepus americanus*, and Red Squirrels, *Tamiasciurus hudsonicus*, in westcentral Montana. Canadian Field-Naturalist 113(3): 386–389.

We investigated winter activity patterns of American Martens, *Martes americana*, Snowshoe Hares, *Lepus americanus*, and Red Squirrels, *Tamiasciurus hudsonicus*, in westcentral Montana between November 1994 and March 1995 using dual-sensor remote cameras. One hundred percent of Snowshoe Hare (n = 25) observations occurred at night while Martens (n = 85) exhibited random activity during diel and nocturnal hours and Red Squirrels (n = 22) were diurnal. Marten activity coincided with the nocturnal and diurnal microtines and diurnal Red Squirrels though they could take advantage of the strictly nocturnal Snowshoe Hares.

Key Words: Marten, *Martes americana*, Snowshoe Hare, *Lepus americana*, Red Squirrel, *Tamiasciurus hudsonicus*, activity patterns, remote cameras, Montana.

Four species of mid-level forest carnivore, American Marten (*Martes americana*), Fisher (*Martes pennanti*), Lynx (*Lynx lynx*), and Wolverine (*Gulo gulo*) are currently thought to be threatened by the loss of late-successional forests (Ruggiero et al. 1994). As such, they have become the focus of attention in an effort to accurately determine their status across the continent and, in doing so, establish baseline levels of occurrence to which future survey results can be compared (Ruggiero et al. 1994; Zielinski and Kucera 1995). Previous studies have addressed regional questions and have provided limited data on distributions (Raphael and Barrett 1981; Barrett 1983; Thompson et al. 1989; Bull et al. 1992; Kucera and Barrett 1993; Fowler and Golightly 1994; Zielinski and Stauffer 1996). However, only recently have efforts been made to coordinate and standardize sampling methods in order to develop a comparable database across a large region (Zielinski and Kucera 1995).

We used remote sensing cameras between November 1994 and March 1995 in westcentral Montana to obtain information on activity patterns of Martens and two species of their prey: Snowshoe Hares (*Lepus americanus*) and Red Squirrels (*Tamiasciurus hudsonicus*).

Study Area

The study was conducted within the Bitterroot Mountains on the Bitterroot National Forest of westcentral Montana (46°30′N, 114°15′W). Four drainages running east to west and spaced approximately 5 km apart were used. These drainages lie within narrow, steep canyons which exhibit an elevational gradient from approximately 1200 m at the floor to over 2500 m at the surrounding peaks. The overstory is characterized by Douglas Fir (*Pseudotsuga menziesii*), Western Larch (*Larix occidentalis*), and Lodgepole Pine (*Pinus contorta*), with Western Red Cedar (*Thuja plicata*) in riparian zones.

Methods

This study was initiated on 30 November 1994 and concluded on 28 March 1995. Remote sensing cameras were employed as described by Foresman and Pearson (1995*, 1998) following the suggested protocols of Kucera et al. (1995). Two dual-sensor remote cameras were placed in adjacent 6.44 km^2 sampling units in four separate drainages, totaling 16 camera stations. Manley camera units (Tim Manley, Kalispell, Montana) mounted 2-3 m above the ground were baited with commercial trapping scents and deer quarters in a "non-reward" manner as per Kucera et al. (1995). Visual observations of Snowshoe Hares and Red Squirrels were recorded while camera units were set and checked.

Camera sets were run continually until 30 days of active camera time was accumulated. Camera sets were checked two days after establishment and at four to seven day intervals to retrieve film and monitor battery life.

Activity patterns for all species detected were determined by categorizing observed occurrences as detections either during nighttime (nocturnal) or day-

*See Documents Cited section.

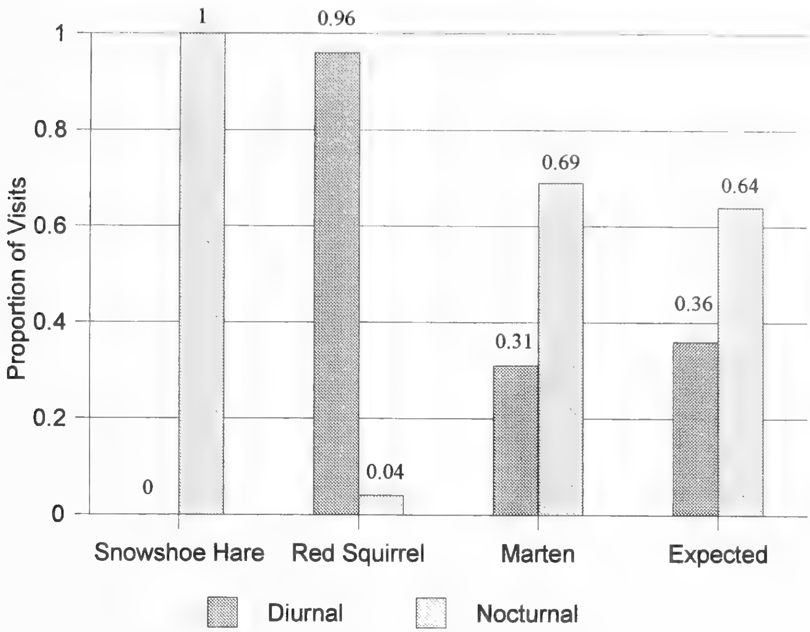

FIGURE 1. Observed nocturnal versus diurnal visitation to remote camera stations for American Martens, Snowshoe Hares, and Red Squirrels compared to expected values based upon median day length for the survey period in the Bitterroot mountains of western Montana, November 1994 to March 1995.

light (diurnal) hours. Nighttime/daylight periods were determined by adding or subtracting 0.5 h respectively to National Weather Service sunrise/sunset time tables. A chi-square goodness-of-fit test with Yates correction for continuity was used to compare observed versus expected values (Zar 1974). Expected values were obtained by using the median day length for the camera survey period. Observations recorded by each camera were treated as independent occurrences when one photograph was obtained separated by 1 h. Thus if individual animals remained at a site creating multiple exposures in a short period of time, such observations would be treated as a single occurrence.

Results

We obtained 85 Marten observations, and we detected Wolverine on two occasions. Eleven additional observations were made on another target species, Fisher (*Martes pennanti*), but since seven were of the same individual during one time period the overall sample size was too small for inclusion in these analyses. Other prey species recorded were Red-backed Voles (*Clethrionomys gapperi*), Deer Mice (*Peromyscus maniculatus*), Red-tailed Chipmunks (*Tamias ruficaudus*), Northern Flying Squirrels (*Glaucomys sabrinus*), Bushy-tailed Woodrats (*Neotoma cinerea*), and Western Jumping Mice (*Zapus princeps*).

Expected values for the chi-square analyses were 8.8 h daylight and 15.3 h nighttime during the study period. Marten activity patterns did not differ from expected (n = 85, χ^2 = 0.858, df = 1, $P < 0.280$) while Hares (n = 25, χ^2 = 12.81, df = 1, $P < 0.001$) were significantly nocturnal as all observations occurred at night (Figure 1). Red Squirrel observations were diurnal (91%; n = 22, χ^2 = 30.56, df = 1, $P < 0.001$). Both observations of Wolverine occurred during the day.

Discussion

Remote camera observations indicated Marten activity was random with respect to diel and nocturnal periods, whereas Red Squirrels, an important prey species of Marten (Weckwerth and Hawley 1962; Gordon 1986), were diurnal. Snowshoe Hares were nocturnal.

Wild Martens have been described as being diurnal in Alberta (More 1978) and nocturnal in Idaho (Marshall 1942) and California (Zielinski et al. 1983) during winter. Zielinski et al. (1983) found a poor correlation between Marten activity patterns and ambient temperatures and suggested that Marten activity patterns in the Sagehen Creek area reflected a synchronization of activity with prey availability rather than an attempt to achieve thermoneutrality.

The primary prey of Marten in the Rocky Mountains is the Red-backed Vole (Koehler and

Hornocker 1977; Weckwerth and Hawley 1962; Cowan and Mackay 1950), but Red Squirrels are an important dietary component reported in 10-12% of scats analyzed in several studies (Gordon 1986; Koehler and Hornocker 1977; Weckwerth and Hawley 1962). Activity patterns of Marten in this study appear to coincide with those reported for microtine rodents much more closely than those of Red Squirrels. Microtines are active throughout the day and night (Hamilton 1937; Davis 1936), while we found Red Squirrels to be almost strictly diurnal. Martens are considered to be generalist predators (Buskirk and Ruggiero 1994) and, therefore, might be expected to exhibit a fairly random activity pattern in foraging for a wide variety of prey.

Snowshoe Hares were strictly nocturnal during winter and, as such, would have been readily available to Marten. Additionally, although the sample size of Fisher detections during this study was too small for statistical analysis, all observations were also made at night. This finding is consistent with observations by deVos (1952) in Ontario, and Coulter (1966) and Arthur and Krohn (1991) in Maine who also found Fishers to be primarily nocturnal [but see Powell (1977) who found Fisher activity random with respect to time of day]. If Fishers synchronize their activity patterns with those of their primary prey (see Curio 1976), Snowshoe Hare activity patterns could largely explain the activity patterns of Fishers in this region.

Our data must be viewed in the context of the time-frame analyzed. Activity patterns of both predator and prey species may vary seasonally. Both Marten (Marshall 1942; Zielinski et al. 1983) and Fisher (Arthur and Krohn 1991) have been shown to alter their activity patterns from winter to summer becoming more diurnal with increasing day length. Recent camera studies conducted between 21 February 1996 and 23 June 1996 support these findings; greater diurnal activity was observed by both Marten and Fisher (37% and 53%, respectively; Foresman and Maples 1996*) than observed in the present study.

In the present study, Snowshoe Hares were not observed during daylight during winter (this pattern was confirmed by camera observations as well), but as spring came and animals began to shed their winter pelts, we began to see animals during the day. Diurnal activity in Snowshoe Hares was recorded 10% of the time in our recent Spring/Summer camera studies. Mech et al. (1966) found that Snowshoe Hares in Minnesota were entirely nocturnal during winter, but during spring and summer months they became largely crepuscular. A switch from crepuscular-diurnal activity during the non-winter period to nocturnal activity in winter is particularly interesting in a species that takes on a white coat in winter presumably for camouflage.

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Documents Cited (marked * in text)

Foresman, K. R., and **D. E. Pearson.** 1995. Testing of proposed survey methods for the detection of wolverine, lynx, fisher, and American marten in Bitterroot National Forest. Final Report for the Research Joint Venture Agreement INT-94918, USDA Forest Service, Intermountain Research Station, Missoula, Montana. 100 pages.

Foresman, K. R., and **M. T. Maples.** 1996. Application of remote sensing methods for the detection of forest carnivores and their prey base in Bitterroot National Forest. Final Report for the Research Joint Venture Agreement INT-96030-RJVA, USDA Forest Service, Intermountain Research Station, Missoula, Montana. 85 pages.

Literature Cited

Arthur, S. M., and **W. B. Krohn.** 1991. Activity patterns, movements, and reproductive ecology of fishers in southcentral Maine. Journal of Mammalogy 72: 379–385.

Barrett, R. H. 1983. Smoked aluminum track plots for determining furbearer distribution and relative abundance. California Fish and Game 69: 188–190.

Bull, E. L., R. S. Holthausen, and **L. R. Bright.** 1992. Comparison of three techniques to monitor marten. Wildlife Society Bulletin 20: 406–410.

Buskirk, S. W., and **L. F. Ruggiero.** 1994. American marten. Pages 7–37 *in* American marten, fisher, lynx, and wolverine in the Western United States. USDA Forest Service, Rocky Mountain Research Station.*Edited by* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski. General Technical Report RM-GTR-254.

Carlson, C. E. 1995. ECO-News, Summer 1995. United States Department of Agriculture Forest Service, Intermountain Research Station, Missoula, Montana. 12 pages.

Coulter, M. W. 1966. Ecology and management of fishers in Maine. Ph.D. dissertation, State University of New York, College of Forestry, Syracuse. 183 pages.

Cowan, I. M., and **R. H. Mackay.** 1950. Food habits of the marten (*Martes americana*) in the Rocky Mountain region of Canada. Canadian Field-Naturalist 64: 100–104.

Curio, E. 1976. The ethology of predation. Springer-Verlag, New York. 250 pages.

Davis, D. H. S. 1936. Rhythmic activity in the short-tailed vole, *Microtus*. Journal of Animal Ecology 2: 232–238.

deVos, A. 1952. Ecology and management of fisher and marten in Ontario. Technical Bulletin, Ontario Department of Lands and Forests. 90 pages.

Foresman, K. R., and **D. E. Pearson.** 1998. Comparison of survey methods for the detection of forest carnivores. Journal of Wildlife Management 62: 1217–1226.

Fowler, C. H., and **R. T. Golightly, Jr.** 1994. Fisher and marten survey techniques on the Tahoe National Forest. Nongame Bird and Mammal Section Report 94-9, State of California, The Resource Agency, Department of Fish and Game, Wildlife Management Division. 64 pages.

Gordon, C. C. 1986. Winter food habits of the pine marten in Colorado. Great Basin Naturalist 46: 166–168.

Hamilton, W. J., Jr. 1937. Activity and home range of the field mouse, *Microtus pennsylvanicus pennsylvanicus* (Ord). Ecology 18: 225–263.

Koehler, G. M., and **M. G. Hornocker.** 1977. Fire effects on marten habitat in the Selway-Bitterroot Wilderness. Journal of Wildlife Management 41: 500–505.

Kucera, T. E., and **R. H. Barrett.** 1993. The Trailmaster® camera system for detecting wildlife. Wildlife Society Bulletin 21: 505–508.

Kucera, T. E., A. M. Soukkala, and **W. J. Zielinski.** 1995. Photographic bait stations. Pages 25–65 *in* American Marten, Fisher, Lynx, and Wolverine: Survey methods for their detection. *Edited by* W. J. Zielinski and T. E. Kucera. General Technical Report PSW-GTR-157. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, California. 163 pages.

Marshall, W. H. 1942. The biology and management of the pine marten in Idaho. Ph.D. dissertation, University of Michigan, Ann Arbor. 107 pages.

Marshall, W. H. 1946. Winter food habits of the pine marten in Montana. Journal of Mammalogy 27: 83–84.

Mech, D. L., K. L. Heezen, and **D. B. Siniff.** 1966. Onset and cessation of activity in cottontail rabbits and snowshoe hares in relation to sunset and sunrise. Animal Behavior 14: 410–413.

More, G. 1978. Ecological aspects of food selection in pine marten. Masters thesis, University of Alberta, Edmonton, Alberta, Canada. 94 pages.

Powell, R. A. 1977. Hunting behavior, ecological energetics, and predator-prey community stability of the fisher (*Martes pennanti*). Ph.D. dissertation, University of Chicago, Chicago, Illinois. 132 pages.

Raphael, M. G., and **R. H. Barrett.** 1981. Methodologies for a comprehensive wildlife survey and habitat analysis in old-growth Douglas-fir forests. Cal-Neva Wildlife Transactions 1981: 106–121.

Ruggiero, L. F., K. B. Aubry, S. W. Buskirk, L. J. Lyon, and **W. J. Zielinski.** 1994. The scientific basis for conserving forest carnivores: American Marten, Fisher, Lynx, and Wolverine in the Western United States. U.S. Forest Service General Technical Report RM-254. 401 pages.

Thompson, I. D., I. J. Davidson, S. O'Donnell, and **F. Brazeu.** 1989. Use of track transects to measure the relative occurrence of some boreal mammals in uncut forest and regeneration stands. Canadian Journal of Zoology 67: 1816–1823.

Weckwerth, R. P., and **V. D. Hawley.** 1962. Marten food habits and population fluctuations in Montana. Journal of Wildlife Management 26: 55–74.

Zar, J. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Clifts, New Jersey. 718 pages.

Zielinski, W. J., and **T. E. Kucera.** 1995. American Marten, Fisher, Lynx, and Wolverine: Survey methods for their detection. General Technical Report PSW-GTR-157. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, California. 163 pages.

Zielinski, W. J., W. D. Spencer, and **R. H. Barrett.** 1983. Relationship between food habits and activity patterns of pine martens. Journal of Mammalogy 64: 387–396.

Zielinski, W. J., and **H. B. Stauffer.** 1996. Monitoring *Martes* populations in California: Survey design and power analysis. Ecological Applications 6: 1254–1267.

Zielinski, W. J., and **R. L. Truex.** 1995. Distinguishing tracks of marten and fisher at track-plate stations. Journal of Wildlife Management 59: 571–579.

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Winter Abundance and Distribution of Shorebirds and Songbirds on Farmlands on the Fraser River Delta, British Columbia, 1989–1991

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Butler, Robert W. 1999. Winter abundance and distribution of shorebirds and songbirds on farmlands on the Fraser River delta, British Columbia, 1989-1991. Canadian Field-Naturalist 113(3): 390–395.

The winter distribution of common shorebirds and songbirds in farmlands on the Fraser River delta, British Columbia, is described for 1989–1991. Most Dunlin (*Calidris alpina*) and Black-bellied Plovers (*Pluvialis squatarola*) roosted in large flocks (median=6450 birds) on beaches during high tides. Smaller flocks (median=507 birds) that flew to farmlands settled in ploughed fields, turf grass and pasture within 2 km of Boundary Bay. Dunlin and Black-bellied Plovers that flew to farmlands mostly foraged there between November and March. The seasonal use of farmlands by Dunlins is probably a trade off between food energy requirements and predation risk from falcons. Forty-five species of songbirds were recorded in farmland hedgerows. Song Sparrow (*Melospiza melodica*), American Robin (*Turdus migratorius*), White-crowned Sparrow (*Zonotrichia leucophrys*), and European Starling (*Sturnus vulgaris*) accounted for over two-thirds of all birds recorded. Shrub hedgerows supported 30 species with a mean of 7.9 individuals detected per census stop versus 40 species with a mean of 18.0 individuals per census stop in tree-hedgerows.

Key Words: shorebirds, predation risk, songbirds, winter, Fraser River delta, British Columbia.

The Fraser River delta in southwestern British Columbia has an abundance of birds in winter (Butler and Campbell 1987; Butler 1997). Thousands of waterfowl and shorebirds frequent Boundary Bay along the delta's southern shore during migration and many stay for the winter (Vermeer and Levings 1977; Butler 1994). Toward the end of the 19th century and in the early 20th century, about three-quarters of the naturally occurring marshes and seasonally flooded grasslands on the Fraser River delta were converted into farmlands (Butler and Campbell 1987; Butler 1997). Today, large numbers of shorebirds, songbirds, waterfowl, and wading birds forage and rest in these farmlands. Many waterfowl depend on farmlands for food during winter (Hirst and Easthope 1981; Baldwin and Lovvorn 1994; Lovvorn and Baldwin 1996). However, the importance of farmlands to shorebirds is less clear. About 30 000 Dunlin (*Calidris alpina*) and 2000 Black-bellied Plover (*Pluvialis squatarola*) spend the winter in Boundary Bay and both species occur in farmlands in winter (Butler 1994; Vermeer et al. 1994). Shorebirds might use farmlands either as an alternate roost site when high tides cover the beaches in water or, alternatively, farmlands might provide shorebirds with foraging sites when food availability wanes on beaches in winter.

Bird conservation programs have largely overlooked hedgerows as bird habitat on the delta in favour of farm fields used by waterfowl. Butler and Campbell (1987) reviewed the status of all birds on the Fraser River delta and showed that 29 species of songbird bred regularly in hedgerows on the delta. However, there are no data on the number of species or abundance of songbirds in hedgerows during the non-breeding season.

Study Area and Methods

I studied shorebirds and songbirds in farmlands and around Boundary Bay on the Fraser River delta between 22 October 1990 and 31 March 1991. Boundary Bay lies on the southern edge of the Fraser River delta about 20 km south of Vancouver, British Columbia. The intertidal portion of the bay was about 5000 ha of mud and sand beach. To the north and east of Boundary Bay was about 19 000 ha of farmland planted mostly in pasture, vegetables and berries with shrub and tree hedgerows. My research was conducted in a 2–2.5 km wide band of farmland that lay to the north of Boundary Bay (Figure 1).

Field methods

I counted the numbers of Dunlin and Black-bellied Plovers that roosted by Boundary Bay and flew into farmlands about once each week from 22 October 1990 to 30 March 1991. Flocks departing Boundary Bay were watched through binoculars until they landed in fields. Once shorebirds had ceased foraging and formed roosting flocks at Boundary Bay, the shortest straight-line distance between each field and Boundary Bay was recorded from a car odometer. Flocks were scanned to record the numbers of resting and foraging Dunlin and plovers. A shorebird was considered to be foraging if it picked or probed the ground while walking whereas shorebirds standing still were considered to be resting.

Hedgerows were divided into shrub-hedgerows and tree-hedgerows. Shrub-hedgerows were continuous bands ranging from about 0.5–2 m high and 3–5 m wide rows of predominantly blackberry (*Rubus* spp.) and rose (*Rosa* spp.). Tree-hedgerows were continuous 1–5 m wide rows of hawthorn (*Crataegus* sp.),

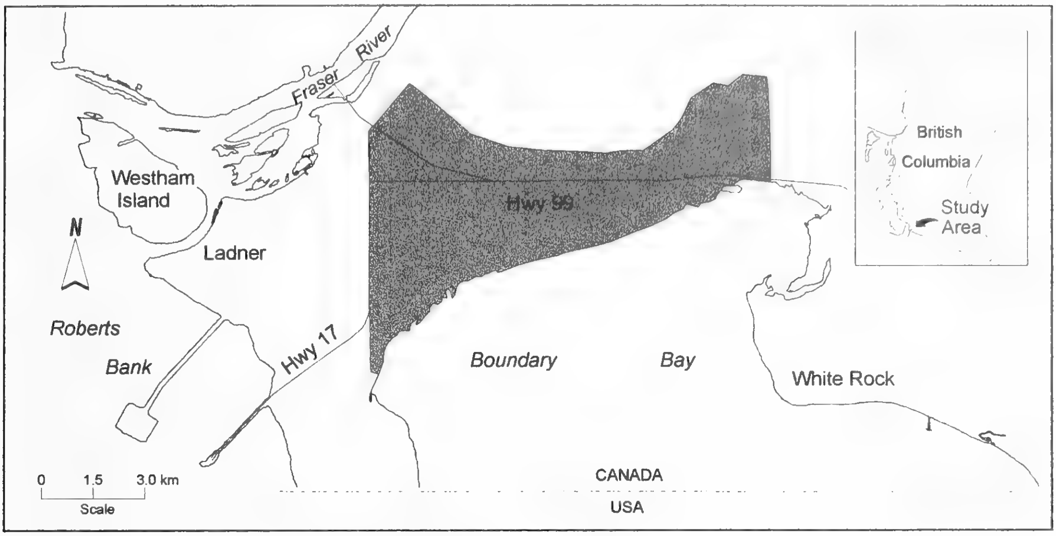

FIGURE 1. Location of study area (shaded) on the Fraser River delta, British Columbia.

crabapple (*Malus* sp.), intermixed with trees spaced at most every 50 m. The predominant tree species were Trembling Aspen (*Populus tremuloides*) and Cottonwood (*P. balsamifera*). The understory shrub layer was mostly rose, blackberry, and Snowberry (*Symphoricarpus albus*). Tree height in tree-hedgerows ranged from about 6–25 m. Bird abundance was estimated by recording all birds heard or seen during 12-minute stops at eight stations spaced at 75-m intervals along hedgerows about once each week for 20 days between 22 October 1990 and 31 March 1991. I also noted the habitat (hedgerow, farm field, or beach) in which mobile avian predators were first detected during shorebird and songbird censuses.

Results

Fewer Dunlin and Black-bellied Plovers were in fields than roosted on the beaches of Boundary Bay. The median size of 28 roosting flocks on beaches was 6450 birds (900–12 000) compared to 507 birds (8–7900) in 48 farmland roosting flocks. The greatest numbers of shorebirds recorded in farmlands on a single day was 11 600 Dunlin on 9 November 1990 and 7108 plovers on 27 October 1990. Dunlin and plovers in fields were mostly foraging between November and March (Table 1). Dunlin and plovers that departed from the beaches settled in fields throughout the 2–2.5 km band of farmland north of Boundary Bay (Table 2).

I detected 45 species of songbirds in hedgerows of which 28 species were common to both shrub- and tree-hedgerows (Tables 3 and 4). Shrub-hedgerows supported fewer species and a lower abundance of songbirds than tree-hedgerows; 30 species with an average of 7.9 individuals per station were detected in shrub-hedgerows compared to 40 species with an average of 18.0 individuals per station in tree-hedgerow. Song Sparrow, American Robin and White-crowned Sparrow made up over 50% of all birds seen in shrub-hedgerows (Table 3). These three species were also numerous in tree-hedgerows and along with the European Starling, amounted to over two-thirds of all birds seen in that habitat (Table 4). Several species of birds of prey were seen in hedgerows. Although Cooper's Hawk was seen more often in hedgerows than in farm fields (19 of 32 sightings) and Merlin was seen more often over farm fields and beaches than in hedgerows (7 of 11 sightings), the habitat segregation was not significantly different between the two species ($\chi^2 = 2.4$, $P > 0.05$). Tall trees in tree-hedgerows were used as perches by several species of birds that foraged in adjacent habitats including Northwestern Crow, Rough-legged Hawk, Rock Dove, Bald Eagle, Northern Shrike, American Kestrel and Brewer's Blackbird. Fox Sparrow was encountered over twice as frequently in shrub-hedgerows as in tree-hedgerows. European Starling, Dark-eyed Junco, Northwestern Crow, Black-capped Chickadee, Bushtit and Bald Eagle were encountered twice as often in tree hedgerows as compared to shrub hedgerows.

Discussion

This study is the first to describe the distribution and behaviour of Dunlin and Black-bellied Plovers on the Fraser River delta farmlands. Most Dunlin and plovers roosted at Boundary Bay rather than departed for fields. However, the Dunlin and plovers

TABLE 1. Percentage of Dunlin and Black-bellied Plovers in farm fields that were foraging between 22 October 1989 to 7 March 1990.

Date	Total	Dunlin % foraging	Total	Black-bellied Plover % foraging
22-31October	753	6.6	3492	0.0
1-14 November	12640	41.7	3420	6.1
15-30 November	13090	43.7	2160	69.6
1-14 December	4031	94.3	1065	83.1
1-14 January	17532	60.1	387	78.3
15-31 January	50	100.0	120	100.0
1-14 February	75	100.0	6	0
1-7 March	10	100.0	350	100.0

that flew to fields settled throughout the farmlands north of Boundary Bay. A key finding in this study was that fields near Boundary Bay were used as foraging habitat as well as high-tide roost sites. Over one-half of the Dunlin and nearly one-third of the plovers that flew to fields foraged there during our study.

One hypothesis to explain the movements of Dunlin and Black-bellied Plovers between Boundary Bay and nearby farm fields is that their behaviour is a trade-off between foraging needs and relative predation risk in the two habitats (predation risk hypothesis). Individuals unable to find sufficient food during low tide, trade-off foraging in the relatively risky farm fields when high tides push them from the beaches of Boundary Bay. A second hypothesis (food limitation) is that shorebirds that are unable to achieve an energy balance during low tides in Boundary Bay, use the fields as an alternate food source during high tides. Although these two hypotheses are not mutually exclusive, the evidence seems to best support the predation risk hypothesis. Both hypotheses assume that Dunlins and plovers use fields as foraging habitat, which concurs with my observations (Table 1). The predation risk hypothesis assumes that predation risk to shorebirds is greater in farm fields than on Boundary Bay. I don't have direct measures of risk but the layout of the two habitats combined with my field observations of the distribution of avian predators supports this notion. Dunlin are a major prey species of Peregrine Falcons and Merlins, and they are occasionally caught by Cooper's Hawks (Page and Whitacre 1975; Buchanan et al. 1991; Warnock 1994; Dekker 1995). Farm fields on the Fraser River delta are partly enclosed by hedgerows from which Merlins, Peregrine Falcons and Cooper's Hawks launched surprise attacks on shorebirds. In contrast, Boundary Bay is an open habitat from which approaching predators were seen from a long way off, and where Cooper's Hawks and Merlins ventured less often than in farmlands. Evidence to support the notion that food becomes limited in Boundary Bay is difficult to directly test but the behaviour of the majority of Dunlins suggests that food is not limited. Most Dunlins do not fly to fields but instead they leave Boundary Bay during high tides to gather for hours in large whirling flocks several kilometers offshore (D. Dekker 1998). This behaviour would be much more energetically costly than roosting or feeding in fields. Low winter body masses of Dunlins in Boundary Bay relative to fall and spring (McEwan and Whitehead 1984) is unlikely a consequence of a mid-winter food shortage since many fly for hours offshore during high tides. Instead, low winter body masses is more likely a facultative response of Dunlins to a perceived risk of predation by falcons (Lima 1986). Dunlin have been reported departing the coast of California during periods of heavy rain (Warnock et al. 1995). However, the fact that shorebirds used fields only when pushed off the beaches by high tides in my

TABLE 2. Number and distance (km) from Boundary Bay of Dunlin and Black-bellied Plovers counted in fields between 22 October 1990 and 31 March 1991.

Distance (km) to nearest beach	Dunlin		Black-bellied Plover	
	Number	%	Number	%
0 - 0.49	7992	22.7	6692	41.5
0.5 - 0.9	2490	7.1	1060	6.6
1.0 - 1.4	10634	30.2	4515	28.0
1.5 - 1.9	9386	26.6	2151	13.3
2.0-2.5	4733	13.4	1696	10.5
	35235		16114	

TABLE 3. Relative frequency and abundance of birds detected in shrub-hedgerows 22 October 1989 to 31 March 1990.

Species	Relative Frequency (N=160 station stops)		Relative Abundance	
	Number of times detected	Percent of times detected	Number detected	Percent of all detections
Song Sparrow (*Melospiza melodia*)	131	81.9	241	15.8
White-crowned Sparrow (*Zonotrichia leucophrys*)	82	51.3	265	17.3
American Robin (*Turdus migratorius*)	55	34.4	292	19.1
Fox Sparrow (*Passerella iliaca*)	29	18.1	31	2.0
Spotted Towhee (*Pipilo maculatus*)	27	16.9	31	2.0
Golden-crowned Kinglet (*Regulus satrapa*)	20	12.5	40	2.6
House Finch (*Carpodacus mexicanus*)	16	10.0	38	2.5
Red-winged Blackbird (*Agelaius phoeniceus*)	10	6.3	42	2.8
Brewer's Blackbird (*Euphagus cyanocephalus*)	9	5.6	213	13.9
Bewick's Wren (*Thyromanes bewickii*)	8	5.0	9	0.6
Black-capped Chickadee (*Poecile atricapillus*)	8	5.0	11	0.7
Ruby-crowned Kinglet (*Regulus calendula*)	6	3.8	11	0.7
European Starling (*Sturnus vulgaris*)	5	3.1	219	14.3
Northern Harrier (*Circus cyaneus*)	4	2.5	5	0.3
Red-tailed Hawk (*Buteo jamaicensis*)	4	2.5	5	0.3
Ring-necked Pheasant (*Phasianus colchicus*)	3	1.9	4	0.3
Purple Finch (*Carpodacus purpureus*)	3	1.9	3	0.2
Dark-eyed Junco (*Junco hyemalis*)	3	1.9	14	0.9
Western Meadowlark (*Sturnella neglecta*)	3	1.9	27	1.8
Bald Eagle (*Haliaeetus leucocephalus*)	2	1.3	2	0.1
Bushtit (*Psaltriparus minimus*)	2	1.3	11	0.7
Yellow-rumped Warbler (*Dendroica coronata*)	2	1.3	3	0.2
Downy Woodpecker (*Picoides villosus*)	2	1.3	2	0.1
Barn Owl (*Tyto alba*)	1	0.6	1	<0.1
Lincoln's Sparrow (*Melospiza lincolnii*)	1	0.6	1	<0.1
Cedar Waxwing (*Bombycilla cedorum*)	1	0.6	3	0.2
Merlin (*Falco columbarius*)	1	0.6	1	<0.1
Cooper's Hawk (*Accipiter cooperi*)	1	0.6	1	<0.1
Northwestern Crow (*Corvus caurinus*)	1	0.6	2	0.1
Bohemian Waxwing (*Bombycilla garrulus*)	1	0.6	2	0.1
Total	441		1530	

study indicates that the preferred foraging location was Boundary Bay. Black-bellied Plovers do not form offshore flocks with Dunlins and fly to farmlands during high tides. Their large eyes might allow them to see approaching predators and thereby reduce the predation risk in fields relative to Dunlins.

My evidence for shorebirds concurs with Lovvorn and Baldwin's (1996) conclusion for waterfowl that farmlands around Boundary Bay are an important source of food in winter. This hypothesis might also explain why the beaches near farmlands in northern Puget Sound and southern Strait of Georgia support some of the greatest winter densities of Dunlin in North America (Root 1988; Paulson 1993).

This study indicated that hedgerows provided habitat for more species of songbird during winter than Butler and Campbell (1987) showed for the migration and breeding seasons. Forty-five species used hedgerows in winter in our study compared to 29 species during spring and summer (Butler and Campbell 1987). In addition, this study concurs with several British studies that showed that tree-hedgerows supported more species than shrub-hedgerows (reviewed by O'Connor and Shrubb 1986; Mills et al. 1991). Songbirds were probably attracted to hedgerows in the present study for food, perches and roost sites. Several species of shrub and tree provided fruit for birds (e.g. *Crataegus*, *Pyrus*, *Sambucus*, *Rubus*, *Cornus*).

The species of birds in tree-hedgerows included all but one species found in shrub-hedgerows. Species found exclusively in shrub hedgerows were the Cedar Waxwing and Bohemian Waxwing, both of which are infrequently seen in winter on the Fraser River delta. These species also inhabit forest edges where they seek out fruits and would likely be eventually found in fruit-bearing tree-hedgerows with more censuses (Butler and Campbell 1987). Of 12 species found only in tree-hedgerows, six species were

TABLE 4. Relative frequency and distribution of birds detected in tree-hedgerows from 22 October 1989 to 31 March 1990.

	Relative Frequency (N=160 station stops)		Relative Abundance	
Speciesl	Number of times detected	Percent of times detected	Number detected	Percent of all detections
Song Sparrow (*Melospiza melodia*)	133	83.1	354	10.5
American Robin (*Turdus migratorius*)	64	40.0	420	12.4
White-crowned Sparrow (*Zonotrichia leucophrys*)	53	33.1	372	11.0
European Starling (*Sturnus vulgaris*)	48	30.0	1194	35.3
Spotted Towhee (*Pipilo maculatus*)	40	25.0	56	1.7
Dark-eyed Junco (*Junco hyemalis*)	32	20.0	224	6.6
House Finch (*Carpodacus mexicanus*)	29	18.1	144	4.3
Northwestern Crow (*Corvus caurinus*)	26	16.3	48	1.4
Black-capped Chickadee (*Parus atricapillus*)	22	13.8	41	1.2
Golden-crowned Kinglet (*Regulus satrapa*)	22	13.8	68	2.0
Bushtit (*Psaltriparus minimus*)	15	9.4	61	1.8
Golden-crowned Sparrow (*Zonotrichia atricapilla*)	12	7.5	27	0.8
Red-winged Blackbird (*Agelaius phoeniceus*)	11	6.9	24	0.7
Bald Eagle (*Haliaeetus leucocephalus*)	10	6.3	16	4.7
Fox Sparrow (*Passerella iliaca*)	9	5.6	14	0.4
Brewer's Blackbird (*Euphagus cyanocephalus*)	9	5.6	190	5.6
Red-tailed Hawk (*Buteo jamaicensis*)	8	5.0	8	0.2
Long-eared Owl (*Asio otus*)	6	3.8	10	0.3
Northern Shrike (*Lanius excubitor*)	5	3.1	5	0.2
Northern Harrier (*Circus cyaneus*)	5	3.1	5	0.1
Ring-necked Pheasant (*Phasianus colchicus*)	5	3.1	16	4.7
Northern Flicker (*Colaptes auratus*)	5	3.1	5	1.4
Bewick's Wren (*Thyromanes bewickii*)	4	2.5	4	<0.1
American Goldfinch (*Carduelis tristis*)	3	1.9	31	0.9
Western Meadowlark (*Sturnella neglecta*)	3	1.9	9	0.3
Cooper's Hawk (*Accipiter cooperii*)	2	1.3	2	<0.1
Ruby-crowned Kinglet (*Regulus calendula*)	2	1.3	3	<0.1
Winter Wren (*Troglodytes troglodytes*)	2	1.3	2	<0.1
Yellow-rumped Warbler (*Dendroica coronata*)	2	1.3	2	<0.1
Sharp-shinned Hawk (*Accipiter striatus*)	2	1.3	2	<0.1
Merlin (*Falco columbarius*)	2	1.3	2	<0.1
Rough-legged Hawk (*Buteo lagopus*)	2	1.3	2	<0.1
Barn Owl (*Tyto alba*)	3	1.9	4	<0.1
Lincoln's Sparrow (*Melospiza lincolnii*)	1	0.6	1	<0.1
Brown-headed Cowbird (*Molothrus ater*)	1	0.6	2	<0.1
Rock Dove (*Columba livia*)	1	0.6	2	<0.1
Purple Finch (*Carpadocus purpureus*)	1	0.6	1	<0.1
Downy Woodpecker (*Picoides villosus*)	1	0.6	1	<0.1
Mourning Dove (*Zenaida macroura*)	1	0.6	1	<0.1
American Kestrel (*Falco sparverius*)	1	0.6	1	<0.1
Total	603		3374	

attracted to the trees for perches or roosting sites (Bald Eagle, Long-eared Owl, Rough-legged Hawk, Rock Dove, Northern Shrike and American Kestrel). Two species prefer forest edges and were probably attracted to the trees (Northern Flicker, Sharp-shinned Hawk) and four species (Golden-crowned Sparrow, American Goldfinch, Brown-headed Cowbird and Mourning Dove) have been seen in shrub-hedgerows at other times (personal observation). Thus, the bird community in shrub-hedgerows appears to be a subset of the community found in tree-hedgerows. Twenty out of 29 breeding species in hedgerows on the Fraser River delta reported by Butler and Campbell (1987) were also present during the non-breeding season in this study. The remaining nine species either do not winter in the Fraser delta or use other types of habitat features not present in our study area. This study confirms that hedgerows in farmlands in the Fraser River delta are used by many species of birds during the non-breeding season.

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Literature Cited

Baldwin, J. R., and **J. R. Lovvorn.** 1994. Habitats and tidal accessibility of the marine foods of dabbling ducks and brant in Boundary Bay, British Columbia. Marine Biology 120: 627–638.

Buchanan, J. B., C. T. Schick, L. A. Brennan, and **S. G. Herman**. 1991. Recovery of prey from water by merlins. Journal of Raptor Research 25: 43–44.

Butler, R. W. 1994. Distribution and abundance of Western Sandpipers, Dunlins, and Black-bellied Plovers in the Fraser River estuary. Pages 18–23 *in* The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia. *Edited by* R. W. Butler and K. Vermeer. Canadian Wildlife Service Occasional Paper Number 83, Ottawa.

Butler, R. W. 1997. The Great Blue Heron. University of British Columbia Press, Vancouver, British Columbia.

Butler, R. W., and **R. W. Campbell.** 1987. The birds of the Fraser River delta: populations ecology and international significance. Canadian Wildlife Service Occasional Paper Number 65, Ottawa.

Dekker, D. 1995. Prey capture by Peregrine Falcons wintering on southern Vancouver Island, British Columbia. Journal of Raptor Research 29: 26–29.

Dekker, D. 1998. Over-ocean flocking by Dunlins, *Calidris alpina*, and the effect of raptor predation at Boundary Bay, British Columbia. Canadian Field-Naturalist 112: 694–697.

Hirst, S. M., and **C. A. Easthope.** 1981. Use of agricultural lands by waterfowl in southwestern British Columbia. Journal of Wildlife Management 45: 454–462.

Lima, S. 1986. Predation risk and unpredictable feeding conditions: determinants of body mass in birds. Ecology 67: 377–385.

Lovvorn, J. R., and **J. R. Baldwin**. 1996. Intertidal and farmland habitats of ducks in the Puget Sound region: a landscape perspective. Biological Conservation 77: 97–114.

McEwan, E. H., and **P. M. Whitehead**. 1984. Seasonal changes in body weight and composition of dunlin (*Calidris alpina*). Canadian Journal of Zoology 62: 154–156.

Mills, G. S., J. B. Dunning, Jr., and **J. M. Bates**. 1991. The relationship between breeding bird density and vegetation volume. Wilson Bulletin 103: 468–479.

O'Connor, R. J., and **M. Shrubb**. 1986. Farming and birds. University of Cambridge Press, Cambridge, United Kingdom.

Page, G. W., and **D. F. Whitacre.** 1975. Raptor predation on wintering shorebirds. Condor 77: 73–83.

Paulson, D. 1993. Shorebirds of the Pacific Northwest. University of Washington Press, Seattle, Washington.

Root, T. 1988. Atlas of wintering North American birds. University of Chicago Press, Chicago, Illinois.

Vermeer, K., R. W. Butler, and **K. H. Morgan**. 1994. Comparison of seasonal shorebird and waterbird densities within the Fraser River delta intertidal regions. Pages 6–17 *in* The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia. *Edited by* R. W. Butler and K. Vermeer. Canadian Wildlife Service Occasional Paper Number 83, Ottawa.

Vermeer, K., and **C. D. Levings**. 1977. Populations, biomass and food habits of ducks on the Fraser Delta intertidal area, British Columbia. Wildfowl 28: 49–60.

Warnock, N. D. 1994. Biotic and abiotic factors affecting the distribution and abundance of a wintering population of Dunlin. Unpublished PhD. dissertation, University of California, Davis, California.

Warnock, N., G. W. Page, and **L. E. Stenzel**. 1995. Non-migratory movements of Dunlin on their California wintering grounds. Wilson Bulletin 107: 131–139.

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Locating the Terminal Bud of Western Redcedar, *Thuja plicata*

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Like all members of the Cupressaceae, Western Redcedar (*Thuja plicata* Donn.) does not produce true resting buds. Furthermore, the primary shoot terminal is difficult to locate because it lacks bud scales, resembles the lateral shoot tips, and is often not the tallest part of the tree. Based on careful monitoring of Western Redcedar shoot development, it was determined that the terminal bud could be distinguished from lateral branches on the basis of a consecutive alternate branching pattern. This pattern provides a simple, non-destructive technique for quick, reliable location of the terminal bud.

Key Words: Western Redcedar, *Thuja plicata*, branching pattern, bud development, shoot growth.

Western Redcedar (*Thuja plicata* Donn., family Cupressaceae) is abundant in the coastal areas and interior "wet belt" regions of northwestern North America. The fragrant, decay-resistant wood of Western Redcedar is of great commercial importance in British Columbia and the Pacific Northwest states due to the widespread use of its old-growth heartwood in North America, Japan and Europe (Warren 1991). Research on the biology of this species has not been extensive in the past but the last two decades have seen increased interest (Minore 1990; Wang et al. 1994). Over the same time period, planting of Western Redcedar as a timber crop has become increasingly common. Planting of Western Redcedar in British Columbia quadrupled from 1985 to 1995, and its percentage of all species planted doubled, but the volume of redcedar logged has consistently declined over the same time period (Anonymous 1987, 1997). Its use as a preferred crop species is bound to increase further because its high shade tolerance (Wang et al. 1994) makes it well suited for regeneration under systems of partial cutting and uneven-aged management. Increased silvicultural use will necessitate more research and monitoring of the biology and growth of this species. To conduct such studies, it is imperative to accurately document the progress of height growth, and therefore, to reliably and repeatedly locate the terminal bud. This is particularly true in standardizing nursery and planting trial measurements.

Western Redcedar has shoots which end in progressively shorter stem leaves which encompass the apical meristem, but the meristem never develops a fully preformed shoot or distinct bud scales (Kozlowski 1971). True terminal buds are never developed (Laubenfels 1953), as buds are defined as having the rudiments for the next year's growth enclosed in bud scales (Kozlowski 1971; Zimmermann and Brown 1977). For lack of a better term and for convenience, the phrase "terminal bud" is used to refer to the first order shoot terminal.

The terminal bud, from which future height growth emanates, is situated at the end of the terminal leader. The terminal leader and terminal bud in most conifers are obvious. In members of the family Pinaceae, the terminal bud is in line with the main axis on the tallest extension of the tree, the terminal leader. However, the terminal leader of redcedar is not so obvious, and neither is the terminal bud. Failure to locate the terminal bud will lead to inconsistent data with greater variability than necessary, usually with over-estimated height and shoot growth determinations. This problem can express itself as irregular (even negative) determinations for height and shoot growth (at a time when growth is actually continuing in a uniform fashion), because the shoot which is assumed to be the leader is different between successive measurements.

This issue of terminal bud location was partially addressed by Parker and Johnston (1987). They suggest counting stem leaf pairs along the main stem to locate the terminal leader (but not the terminal bud) from which future height growth will emanate. In attempting to apply this method, we found it to be very time consuming. The method also relies on the perception that there were more stem leaf pairs between branches than between branchlets or between branches and branchlets. During the course of estimating the age of redcedar seedlings from morphological attributes (Trevor 1992), it was determined that this generalization was not always true.

Western Redcedar has a terminal bud that is morphologically very similar to the terminal buds of the laterals (Parker and Johnston 1987). The terminal bud is seldom the tallest part of the tree (as in members of Pinaceae), however, and the terminal leader

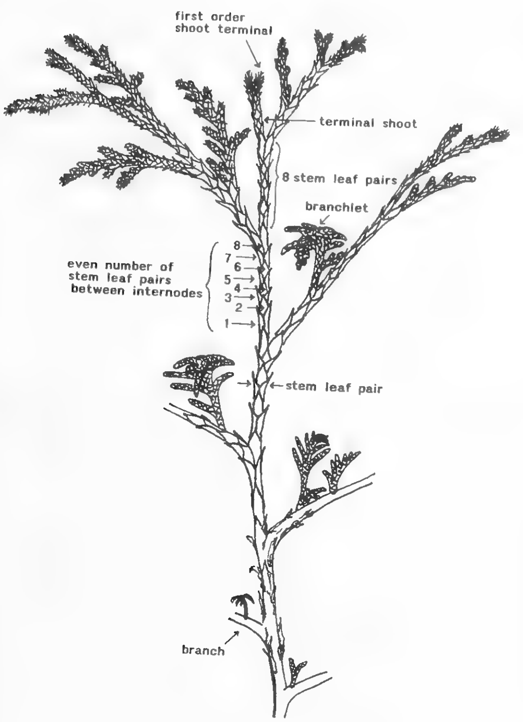

FIGURE 1. Labelled example of a Western Redcedar leader, illustrating the morphological features and terms referred to in the text.

often looks like a suppressed branch to the side of what appears to be the main axis. The newly forming branch seems to exert apical dominance over the terminal leader for a short time and grows faster during the initial phases of development. As growth continues, the branch is forced to the side and the terminal leader becomes more erect on the main axis of the tree. It is therefore not obvious which shoot tip contains the true terminal bud, because all the primary and secondary terminal buds are similar and the terminal bud and the terminal leader are seldom the tallest parts of the tree.

To determine the true terminal leader and terminal bud, the growth of a number of cedars was charted on a monthly basis. From these observations it became quite clear which bud was the terminal bud, and therefore which part was the terminal leader, in every case. The method outlined below allows a conscientious observer to quickly and accurately locate the terminal bud of Western Redcedar for measurement purposes.

Morphology

To understand the method proposed for locating the terminal bud of Western Redcedar, it is necessary to review the shoot morphology of this species (Figure 1).

Buds

Western Redcedar has indeterminate growth (Krasowski and Owens 1990), and its buds therefore lack fully preformed shoots (Kozlowski 1971; Laubenfels 1953). The buds are small, lack bud scales, and are covered in leaf primordia (Krasowski and Owens 1990). Externally, the buds of lateral branches and the terminal bud appear identical in structure. The "bud" in Western Redcedar, as in all members of the family Cupressaceae, is a resting state of the elongating shoot (Mitchell 1965; Aldhaus and Low 1974) as there are no special overwintering buds (Laubenfels 1953; Minore 1990).

Leaves

Western Redcedar displays four types of leaves: cotyledons, juvenile leaves, and mature leaves which can be divided into stem leaves and scalelike leaves. Depending on the growth rate of the seedling, it may take two to several years before only mature stem leaves are present at the terminal bud. The mature scalelike leaves are decurrent and found in pairs at right angles to each other, and the stem leaves are usually in whorls of four leaves and occasionally in whorls of three leaves (Krasowski and Owens 1990). It is these pairs of stem leaves that Parker and Johnston (1987) attempted to use in locating the terminal, as there are usually more leaf pairs between branches on the main stem than between the branch axil and the first branchlet (Parker and Johnston 1987). However, this pattern does not always hold true. Several trees were observed in which the number of stem leaf pairs between the branches was less than or equal to the number of stem leaf pairs between the branch axil and the first branchlet. Though the usual number was six or eight stem leaf pairs between branches, as many as 14 and as few as two stem leaf pairs were observed between the branches of various Western Redcedar leaders monitored during the course of this study.

Branching

On the terminal stem, new branches are formed one at a time on alternating sides of the main stem at an angle of 180 degrees to each other. However, on lateral stems (branches), the first two or three branchlets may occasionally be produced on the upward side before beginning to alternate sides. Furthermore, laterals in their early stages of development tend to be oriented in the vertical plane, making one appear like the leader for a period of time. Branching universally occurs on even numbers of stem leaf pairs (Parker and Johnston 1987). The alternating branching pattern causes the tree to grow in one plane. But as the tree grows it twists or spirals (Parker and Johnston 1987), making it appear that the branches radiate out from the main stem in all directions.

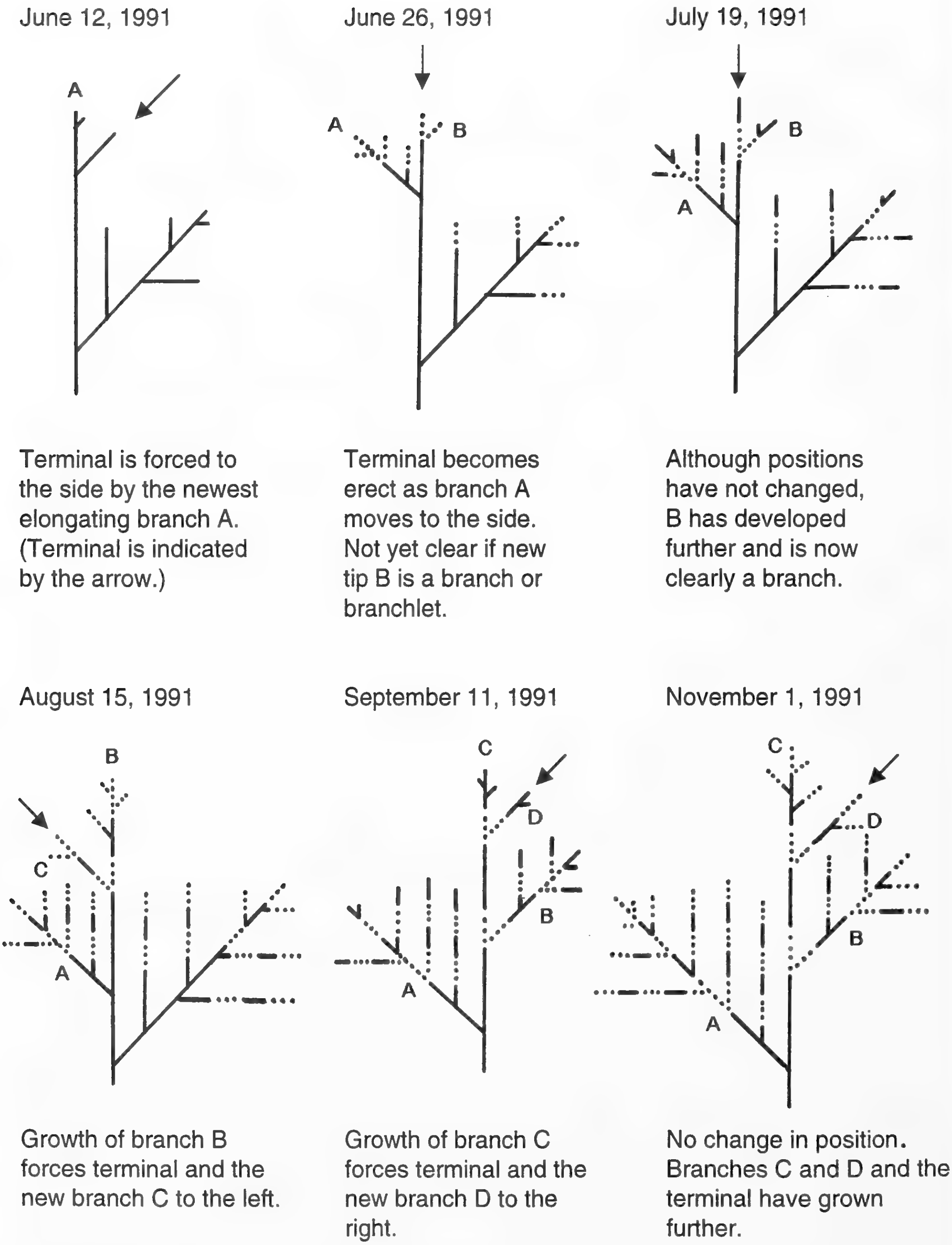

FIGURE 2. Charted growth of a representative Western Redcedar leader (tree number 5). The arrow indicates the first order shoot terminal, while letters designate particular branches which may change position from month to month. Note that the terminal leader and the terminal bud are seldom the tallest parts of the tree, and that these parts are constantly changing position. Sketches are skeletal only, following the first order shoot terminal's development; growth is not drawn to scale.

TABLE 1. Height difference between the tallest part and the terminal bud in Western Redcedar

		Mean Height		Height Difference	
Month	n*	Terminal Bud	Tallest Part	Mean	Standard Deviation
		(cm)	(cm)	(cm)	(cm)
June	17	93.2	95.6	2.4	3.80
July	17	100.0	102.4	2.4	3.07
September	15	106.7	110.3	3.6	4.01
November	15	107.9	112.5	4.6	5.05

* Sample size was initially 18, but mortality and vandalism reduced it to 15.

Monitoring of Shoot Development

The growth of 18 four-year old cedars was charted monthly for six months (June to November 1991). On each chart, the tree's top 40-50 cm was drawn in a line sketch in which all laterals and buds were recorded (Figure 2). Also recorded for each tree were two height measurements: the height from the ground to the tallest part of the tree, which was determined by orienting all upper branches vertically; and the height from the ground to the tallest part of the terminal leader, which was originally located using Parker and Johnston's (1987) method of counting stem leaf pairs and confirmed in the second and subsequent observations. The charts were compiled each month for each of the 18 trees. It became obvious after the second month which resting buds were on branches and which resting bud was the true terminal; observations over the following months confirmed these determinations. These six months of observations resulted in a rapid and accurate method for locating the terminal bud.

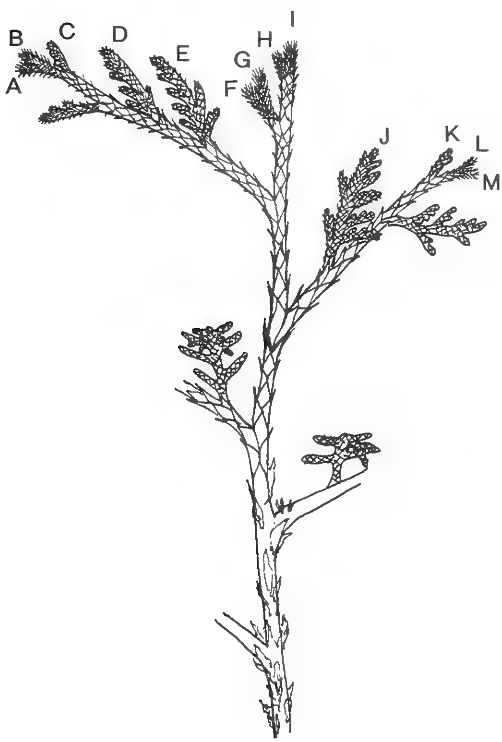

FIGURE 3. A second example of a Western Redcedar leader, exhibiting a different shoot tip morphology than shown in Figure 1, for practice in determining the terminal bud location.

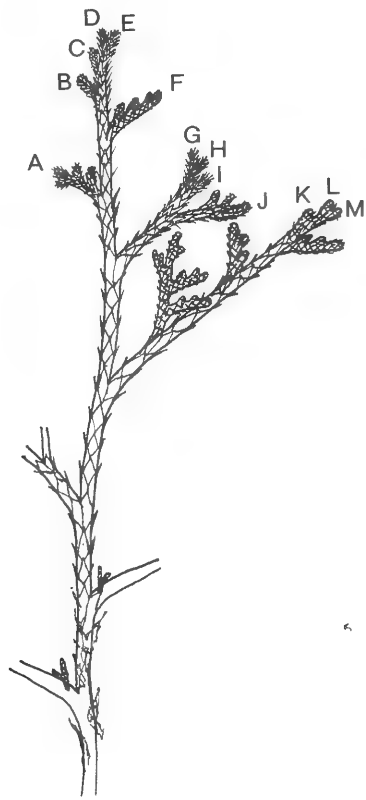

FIGURE 4. A third example of a Western Redcedar leader, representing a shoot morphology different than those portrayed in Figure 1 or 3, for further practice in determining the terminal bud location.

Height Development

That newly formed branches near the terminal bud tend to be taller than the terminal bud (Parker and Johnston 1987) was confirmed during the monitoring exercise (Table 1). The tallest part of the tree (usually recorded as "height" in growth measurements) averaged 2.4 to 4.6 cm taller than the terminal, and this difference was highly variable.

The bias in estimates increased markedly towards the end of the growing season, typically the end of October. This is due to the fact that the branches continue to elongate while the terminal leader produces very little new growth during September and October. While the terminal bud is clearly entering a quiescent state, it gives no morphological indication of this change.

How To Locate the Terminal "Bud"

The monitoring of shoot development in Western Redcedar seedlings revealed that branching reliably occurs on alternating sides. Therefore it is possible to eye the branches from side to side on the uppermost part of the leader until the terminal bud is reached. This allows for quick and accurate terminal bud location.

The sequential details of the method proceed as follows (for assistance use Figures 1, 3, and 4):

1) On the leader, locate a definite branch (the third or fourth branch from the top will do);
2) Proceed up the main stem to the next branch (which will *always* be on the opposite side);
3) Continue upwards through successive branches until a final bud is located, the true terminal bud (Figure 1), or until two 'branches' appear to be on the same side (A-E and F-I in Figure 3, and G-J and K-M in Figure 4);
4) Determine which "branch" would be the true branch by continuation of the side-to-side method. The branch that appears to be the continuation of the main stem and terminal is actually the branch on the opposing side of the lower, previous branch. Counter-intuitively, if two branches appear to be on the same side of a taller vertical axis, then the vertical apex (H-I in Figure 3, A-F in Figure 4) must be the true branch and the uppermost "branch" (F-G in Figure 3, G-J in Figure 4) must be the continuation of the main stem, as the branches must alternate;
5) Now proceed up the main stem (though it may appear to be a branch) applying steps 3 and 4 until the terminal bud is reached.

The terminal bud for Figure 1 is indicated; in Figure 3 the terminal bud is G, and the terminal bud in Figure 4 is I.

This method can seem confusing for the novice. But after working through a few examples (i.e., Figures 1, 3, and 4) it should become easier to apply the "side-to-side" method. If unsure as to the identity of the terminal among the last few stems, Parker and Johnston's (1987) method can be applied to guide one up the correct stem to the terminal. However, because of the telescoped nature of the final few buds it is very hard to count the individual stem leaf pairs and determine the terminal bud. The "side-to-side" method proposed here solves this problem of ambiguity at the very tip where two or more telescoped buds are always located. With some practice, this method enables the scientist, nurseryperson and field worker to quickly and accurately locate the true terminal bud of young and maturing Western Redcedar trees.

Literature Cited

Aldhaus, J. R., and **A. J. Low.** 1974. The potential of western hemlock, western redcedar, grand fir and noble fir in Britain. Forestry Commission Bulletin Number 49. London, U.K.

Anonymous. 1987. Annual report of the Ministry of Forests for the fiscal year ended March 31, 1986. British Columbia Ministry of Forests, Victoria, British Columbia.

Anonymous. 1997. Annual report of the Ministry of Forests for the fiscal year ended March 31, 1996. British Columbia Ministry of Forests, Victoria, British Columbia.

Kozlowski, T. T. 1971. Growth and development of trees, Volume 1. Academic Press, New York.

Krasowski, M. J., and **J. N. Owens.** 1990. Growth and morphology of western redcedar seedlings as affected by photoperiod and moisture stress. Canadian Journal of Forest Research 21: 340–352.

Laubenfels, D. J. 1953. The external morphology of coniferous leaves. Phytomorphology 3: 1–20.

Minore, D. 1990. *Thuja plicata* Donn. ex D. Don — Western Redcedar. Pages 590–600 *in* Silvics of North America: Volume 1. Conifers. *Technical coordinators* R. M. Burns and B. H. Honkala. Agriculture Handbook 654, U.S. Forest Service, Washington, D.C.

Mitchell, A. F. 1965. The growth in early life of the leading shoot of some conifers. Forestry 38: 121–136.

Parker, T., and **F. D. Johnston.** 1987. Branching and terminal growth of Western Redcedar. Northwest Science 61: 7–12.

Trevor, M. 1992. First order shoot terminal location and the estimation of age in young western redcedar trees using morphological attributes. Bachelor of Science in Forestry (B.S.F.) thesis, Faculty of Forestry, University of British Columbia, Vancouver, British Columbia.

Wang, G. G., H. Qian, and **K. Klinka.** 1994. Growth of *Thuja plicata* seedlings along a light gradient. Canadian Journal of Botany 72: 1749–1757.

Warren, D. D. 1991. Production, prices, employment, and trade in the Northwest forest industry: First quarter 1991. PNW-RB 188, U.S. Forest Service, Portland, Oregon.

Zimmerman, M. H., and **C. L. Brown.** 1977. Trees: Structure and function. Springer-Verlag, New York.

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Food Resources and Diet Composition in Riparian and Upland Habitats for Sitka Mice, *Peromyscus keeni sitkensis*

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Food resources and diet composition of Sitka Mice, *Peromyscus keeni sitkensis*, were studied over a four-year period in four floodplain and upland forest habitats: old-growth Sitka Spruce (*Picea sitchensis*) floodplain; Red Alder (*Alnus rubra*) floodplain; Beaver (*Castor canadensis*)-pond floodplain; and nearby old-growth Sitka Spruce-Western Hemlock (*Tsuga heterophylla*) upland forest. Food resources in each habitat were quantified in terms of understory biomass and species richness, fruit production, tree seedfall, and relative abundance of arthropods. Diet composition was analyzed from stomach contents. Between-year differences in the availability of food resources were substantial, but between-habitat differences were minor. Diet composition differed between years and between months within years but did not differ between habitat types or age and sex classes of mice. We conclude that floodplain habitats do not provide unique food resources for Sitka Mice in comparison to upland old-growth forests. However, spatial and temporal complexity within habitats is an important feature of habitat quality in floodplain forests for *Peromyscus* mice.

Key Words: Sitka Mouse, *Peromyscus keeni sitkensis*, riparian forest, river, habitat heterogeneity, temporal variation, southeastern Alaska.

The Sitka Mouse (*Peromyscus keeni sitkensis*) occurs on some of the outer-coast islands of the Alexander Archipelago of southeastern Alaska (Nagorsen 1990; Hogen et al. 1993). Like other *Peromyscus* species, it prefers a diet of seeds and fruits (Reese et al. 1997) but also eats a wide variety of leaves, insects and other invertebrates. Little is known of the ecology of Sitka Mice, however, because few field studies have been conducted in its relatively remote range.

The habitat of the Sitka Mouse is primarily Sitka Spruce-Western Hemlock (*Picea sitchensis-Tsuga heterophylla*) coastal rain forest with understories dominated by Blueberry (*Vaccinium* spp.), Devilsclub (*Oplopanax horridus*), Skunkcabbage (*Lysichiton americanum*), and Lady Fern (*Athyrium filix-femina*) (Hanley and Brady 1997). The forests are excessively wet, and streams and rivers are common. Red Alder (*Alnus rubra*) is a common overstory species along stream channels and also occurs in uplands where soil disturbance has exposed much mineral soil (Ruth and Harris 1979).

The objectives of our study were to quantify patterns in diet composition of Sitka Mice in riparian and upland forests and to relate diet composition to the relative availability of food resources. Differences in forest vegetation in the region are most pronounced between uplands and floodplains (Hanley and Brady 1997). Beaver ponds within floodplains also provide uniquely different habitat from the surrounding mosaic (Pollock et al. 1998). Our study, therefore, concentrated on four major types of forest habitat: old-growth Sitka Spruce floodplain, Red Alder floodplain, Beaver-pond floodplain, and old-growth Sitka Spruce-Western Hemlock upland forest.

Methods

Study area and vegetation

The study was conducted in May-September during four summer field seasons, 1992-1995, in the Kadashan River drainage (57°42′N, 135°13′W) of Chichagof Island, Alaska. Kadashan River is a fourth-order stream with an average bankfull width of about 25 m in the areas that we studied. The floodplain extended about 150 m on both sides of the river and was subject to periodic flooding throughout the year but most commonly in October-November (Pollock 1995). The climate of the study area was maritime with cool summer temperatures (mean about 15 ± 5°C), mild winter temperatures (mean about 0 ± 5°C), and much precipitation (about 1500-3500 mm/yr) year-around (see Farr and Hard 1987).

The forests were old-growth Sitka Spruce-Western Hemlock, with Sitka Spruce dominating in the floodplains and sharing dominance with Western Hemlock in the uplands. Red Alder (*Alnus rubra*) dominated a 14-ha portion of the floodplain that was logged in 1953.

Two stands of each of the three types of forest were selected for study. Only one Beaver-pond stand was studied, as it was the only one in the vicinity. It had been old-growth Sitka Spruce floodplain before Beaver impoundment.

Both the overstory and understory vegetations of the six forest stands were studied in detail in 1993 (Hanley and Hoel 1996). Those understory data, and similar data for the Beaver pond (Pollock 1995), were subjected to an agglomerative cluster analysis (Goldsmith and Harrison 1976) based on proportional similarity matrices (Pielou 1977). This procedure quantified the vegetation similarity between stands and habitat types.

Food resources

We considered food resources to be aboveground, understory biomass, fruits, arthropods, and tree seeds. We could not monitor all food resources in all stands in all years, and we assumed that the relative availability of edible foods other than tree seeds would correlate with relative differences in understory biomass and species richness. We did not try to directly estimate the availability of seeds of understory plants.

Fruits of understory plants were monitored monthly throughout the growing season in 1994 and 1995 in permanently located 1.0-m^2 plots in each of the seven stands. Six plots per stand were monitored in 1994; 20 plots per stand were monitored in 1995. Plot locations were randomly assigned to numbered grid coordinates within the sample areas of each stand. Fruits within each plot were counted, and samples of each species were taken from each stand for oven-dry weight (100°C) determination.

Arthropods were monitored in three ways: timed counts, pitfall traps, and "beetle boards" (see below). All sampling locations were randomly assigned to numbered grid coordinates within each stand. Counts were conducted in 0.5-m^2 plots within each stand each month of the field season, 10 plots per stand in 1993, six plots per stand in 1994 and 1995. All arthropods seen during a 2.0-min search of the plot by two observers were counted by category, and the two observers' counts were averaged. Pitfall traps were 76-mm-diameter, 450-ml glass jars buried to the lip, filled to 2.5-cm depth with 50:50 (volume) propylene glycol:water, and covered with an aluminum sheet 1.0 cm above for crawl space and protection from rain and contamination. Pitfall traps were closed with jar lids when not in use. Traps were open for five consecutive days each month in each stand, six pitfalls per stand in 1994, 20 pitfalls per stand in 1995. Contents were screened and stored in vials of 70% (volume) ethanol. Specimens were identified in most cases to order. Beetle boards were 0.1-m^2 boards left on the ground and monitored monthly in 1994 and 1995, six per stand in both years. All arthropods observed by one observer were tallied within a 30-second count after lifting the board and looking for arthropods beneath it.

Tree seedfall was monitored from June 1993 through September 1995. Seed traps, measuring 54 × 93 × 10 cm and elevated 50 - 250 cm above ground surface to avoid shading from understory, were covered on top and bottom with 1.0-cm hardware cloth and lined with polyester interfacing cloth. Traps were set up in June 1993, and seeds were collected in June 1994, April 1995, and September 1995. Six traps per stand were equidistantly spaced throughout the 1.2-ha sampling areas of each forest stand and the Beaver-pond stand in 1993. Four traps per stand were monitored in all seven stands in 1994 - 1995. Seeds were sorted from the trap contents, oven-dried (100°C), and weighed.

Diet composition

Diets were determined by stomach analysis of mice captured on or near the food-resource sampling areas of each stand. Snap-trap transects were established off the food-sampling areas but in similar habitat during 1992 and 1993, when Sitka Mouse populations were low. Accidental live-trap mortalities on the food-sampling areas provided sufficient samples during the higher population years of 1994 and 1995. Only animals with little oatmeal bait in their stomachs were used from the live-trap mortalities; all oatmeal was ignored in the stomach analysis. We obtained 47 specimens in 1992, 27 in 1993, 19 in 1994, and nine in 1995. We obtained 22 specimens from the spruce habitat type, 23 from alder, 36 from upland, and 20 from the Beaver pond.

Stomach contents were removed from each animal and stored in 70% (volume) ethanol. Samples were prepared for microscopic analysis by staining with Harris hematoxyln as described by Hansson (1970). Slides were examined at 100× under a light microscope, and percentage cover of food categories was estimated in 10 microscope fields per slide, two slides per stomach (Van Horne 1982a). Food categories included arthropod, leaf, fruit/seed (not tree), spruce/hemlock/alder seed, and fungi. Such broad categories minimized problems of sample misidentification.

Statistical analyses

All differences between means were tested with one-way analysis of variance, with significant differences followed by Student-Newman-Keuls test for multiple comparisons (Zar 1974). Diet composition data were percentages and so were transformed with arcsine transformation before analysis. Diet composition categories also were compared with multivariate analysis of variance (Wilkinson et al 1992). An alpha level of 0.05 was used as the criterion of statistical significance throughout.

Results

Habitat classification

Cluster analysis of the species-specific understory-biomass data indicated that each of the "replicate" forest stands was more similar to each other than to other habitat types. The spruce and alder floodplain forests were most similar among habitat types (pro-

TABLE 1. Biomass and number of species in understory vegetation of each of the three forest habitat types ($\bar{x}$ ± SE, 2 stands each; data calculated from Hanley and Hoel 1996) and the Beaver pond (calculated from Pollock 1995).[1]

Biomass/No. species	Spruce floodplain	Alder floodplain	Upland	Beaver pond
Biomass (g/m^2)				
Total shrubs	385 ± 56	223 ± 17	272 ± 16	140
Total forbs	7 ± 2[a]	10 ± 0[a]	23 ± 14[a]	94[b]
Total ferns	27 ± 10	28 ± 10	2 ± 1	4
Total graminoids	<1 ± <1[a]	<1 ± <1[a]	<1 ± <1[a]	30[b]
Number of species[2]				
Shrubs	3 ± 1	5 ± 1	5 ± 1	5
Forbs	10 ± 1	12 ± 3	11 ± 2	23
Ferns	4 ± 0	5 ± 14	3 ± 0	4
Graminoids	1 ± 1[a]	2 ± 2[a]	2 ± 2[a]	13[b]

[1]Species-specific data are available in Hanley and Hoel (1996) and Pollock (1995). Values with different superscripts within the same row differ at the 0.05 level (analysis of variance and Student-Newman-Keuls test; Zar 1974).
[2]Only species with biomass >0.1 g/m^2 are included. The five most dominant (greatest biomass) species in each of the habitats were as follows: (1) Spruce floodplain — *Oplopanax horridum*, *Ribes bracteosum*, *Athyrium filix-femina*, *Gymnocarpium drypoteris*, *Tiarella trifoliata*; (2) Alder floodplain — *R. bracteosum*, *O. horridum*, *A. filix-femina*, *Rubus spectabilis*, *Dryopteris dilatata*; (3) Upland — *Vaccinium alaskensis*, *V. ovalifolium*, *Menziesia ferruginea*; *Lysichiton americanum*, *R. spectabilis;* (4) Beaver pond — *O. horridum*, *R. spectabilis*, *Angelica genuflexa*, *Equisetum arvense*, *Arabis lyrata*.

portional similarity 0.701), and the upland forest was least similar to all other types (proportional similarity 0.068). The Beaver pond was more similar to the floodplain forests (proportional similarity 0.280) than to the upland forest (proportional similarity 0.047).

Food resources

Despite high similarities within habitat types and great differences between habitat types in species composition and structure of overstories (Hanley and Hoel 1996) and species composition of understories (above), such patterns did not carry through to apparent availability of food resources. Rather, much variation occurred between replicate stands of the same habitat type and between relative availabilities of various food categories. Overall, the Beaver-pond habitat appeared to be richest in variety of understory seeds and fruit, the upland forests most productive of Blueberries, the spruce floodplain forests most productive of Devilsclub berries, all habitats equally

TABLE 2. Fruit production (oven-dry weight, g/100 m^2) in each of the three forest habitat types ($\bar{x}$ ± SE, 2 stands each) and the Beaver pond.[1]

Time/species	Spruce floodplain	Alder floodplain	Upland	Beaver pond
May - September 1994[2]				
Blueberry[3]	1.0 ± 1.0	0 ± 0	233.9 ± 71.9	2.6
Stink Currant[4]	149.4 ± 137.1	6.1 ± 6.1	0 ± 0	0
Salmonberry[5]	7.0 ± 7.0[a]	0 ± 0[a]	0 ± 0[a]	101.5[b]
May - September 1995				
Blueberry	3.4 ± 3.4[a]	0 ± 0[a]	84.5 ± 8.8[b]	0[a]
Stink Currant	61.5 ± 60.9	9.4 ± 9.4	0 ± 0	31.5
Salmonberry	0 ± 0	5.1 ± 5.1	0 ± 0	7.2
Devilsclub[6]	15.3 ± 1.8[b]	2.5 ± 1.8[a]	0 ± 0[a]	2.5[a]
Twisted-stalk[7]	0 ± 0	0.4 ± 0.4	0.1 ± 0.1	4.5
Bunchberry[8]	0.1 ± 0.1	0 ± 0	0.6 ± 0.3	0.1
Skunkcabbage[9]	0 ± 0	0 ± 0	5.0 ± 5.0	19.0
Elderberry[10]	0 ± 0	55.7 ± 55.7	0 ± 0	0.8
Deerberry[11]	0 ± 0	3.1 ± 1.0	0 ± 0	0.8

[1]Values with different superscripts within the same row differ at the 0.05 level (analysis of variance and Student-Newman-Keuls test; Zar 1974).
[2]Only 3 species were monitored in 1994.
[3]*Vaccinium alaskensis* and *V. ovalifolium*
[4]*Ribes bracteosum*
[5]*Rubus spectabilis*
[6]*Oplopanax horridum*
[7]*Streptopus* spp.
[8]*Cornus canadensis*
[9]*Lysichiton americanum*
[10]*Sambucus racemosa*
[11]*Maianthemum dilatatum*

TABLE 3. Total biomass of arthropods (g/100 trap-days; $\bar{x} \pm$ SE) captured in pitfall traps in each of the three forest habitat types (two stands each) and the Beaver pond.[1]

Time	Spruce floodplain	Alder floodplain	Upland	Beaver pond
1994[2]	4.8 ± 1.4	8.7 ± 4.9	7.4 ± 0.1	4.7 ± 0.8
1995[2]	9.8 ± 0.7	15.9 ± 2.1	8.3 ± 1.5	9.8 ± 5.1
May[3]	2.4 ± 0.2	5.0 ± 1.1	2.6 ± 0.2	1.8 ± 0.1
June[3]	6.9 ± 2.4	6.9 ± 0.6	6.6 ± 3.0	2.9 ± 2.0
July[3]	4.3 ± 1.6	5.5 ± 1.5	6.9 ± 0.8	6.1 ± 0.1
August[3]	11.9 ± 0.6	15.6 ± 2.2	9.4 ± 0.9	9.1 ± 2.5
September[3]	11.2 ± 2.2	28.4 ± 8.3	14.0 ± 0.9	16.4 ± 12.4

[1]No means within the same row differ at the 0.05 level (analysis of variance; Zar 1974).
[2]Mean of May - September.
[3]Mean of 1994 and 1995.

productive of arthropods, and the alder floodplain forests most productive of Red Alder seed. Variation within habitat types and between years, however, was substantial.

Total understory biomass varied from 261 to 419 g/m^2 in the four habitat types and was strongly dominated by shrubs in all three forest types (Table 1). Shrubs dominated the vegetation of the Beaver pond, too, but forbs and graminoids were much more abundant there than anywhere else, both in biomass and species richness (Table 1). Although total understory biomass was similar among all habitat types, species richness of the Beaver pond was about twice that of the forests. Patterns in understory biomass and species richness, therefore, indicated only that the diversity of seed and vegetative food resources was probably greater in the Beaver pond than in any of the forests. Vegetation biomass peaked in July and August each year (Pollock 1995).

Patterns in fruit production followed those of understory vegetation, with species diversity and Salmonberry production being greatest in the Beaver pond, Blueberry being greatest in the upland forests, and Devilsclub being greatest in the spruce floodplain forests (Table 2). Stink Currant (*Ribes bracteosum*) was another abundant fruit in floodplain habitats. The availability of fruit peaked in July and August. Total fruit production, however, varied greatly between years, habitat types, and replicate stands within habitat types (Table 2).

We considered pitfall traps to be our most reliable and objective estimator of relative abundance of arthropods because traps were free of the observer error that was inherent in rapid counting and identification in the other two methods. Pitfall traps indicated that although substantial variation existed between years, arthropod abundance consistently increased throughout the trapping season, May through September (Table 3). We found no significant differences ($P < 0.05$) in relative abundance between habitat types, but all three techniques (including timed-counts and beetle-board methods) yielded highest values in the alder floodplain forests.

Although tree seedfall, too, varied substantially between years and between replicate stands within habitat types, Sitka Spruce was consistently the most abundant species in all time periods and most habitats (Table 4). Patterns in tree seedfall largely corre-

TABLE 4. Overstory seedfall (oven-dry weight, g/100 m^2) in each of the three forest habitat types ($\bar{x} \pm$ SE, 2 stands each) and the Beaver pond.[1]

Time/species	Spruce floodplain	Alder floodplain	Upland	Beaver pond
June 1993 - June 1994				
Sitka Spruce	72.6 ± 57.3	32.5 ± 31.0	7.7 ± 3.6	5.1
Western Hemlock	31.4 ± 19.7	4.0 ± 4.0	9.9 ± 5.5	2.2
Red Alder	0 ± 0	3.0 ± 1.5	11.7 ± 11.7	0
June 1994 - April 1995				
Sitka Spruce	88.2 ± 49.3	75.1 ± 56.9	14.0 ± 11.6	62.0
Western Hemlock	3.4 ± 2.2	1.5 ± 1.5	5.8 ± 1.5	1.8
Red Alder	1.8 ± 1.8[a]	66.0 ± 5.8[b]	1.8 ± 1.8[a]	0[a]
April 1995 - September 1995				
Sitka Spruce	10.6 ± 5.4	2.8 ± 1.3	1.1 ± 0.8	4.6
Western Hemlock	0.9 ± 0.9	0 ± 0	1.7 ± 0.5	0
Red Alder	0 ± 0	37.0 ± 35.2	0 ± 0	0

[1]Values with different superscripts within the same row differ at the 0.05 level (analysis of variance and Student-Newman-Keuls test; Zar 1974).

TABLE 5. Percentage composition ($\bar{x}$ ± SE) of food fragments in stomach samples of Sitka Mice in the study area.[1]

Habitat/class/time[2]	Arthropod	Leaf	Fruit/seed	Tree seed	Fungi
Habitat type					
Spruce floodplain (22)	15.1 ± 5.1	9.1 ± 3.9	70.5 ± 5.8	5.2 ± 2.1	< 0.1 ± < 0.1
Alder floodplain (23)	6.0 ± 3.2	13.2 ± 4.9	63.7 ± 8.1	17.2 ± 7.0	< 0.1 ± < 0.1
Upland (36)	3.6 ± 2.8	8.4 ± 3.1	69.4 ± 6.2	16.7 ± 5.1	1.8 ± 1.1
Beaver pond (20)	6.8 ± 2.8	9.6 ± 4.9	72.0 ± 7.8	11.4 ± 6.6	0
Age/sex class					
Adults (56)	4.9 ± 1.5	7.5 ± 2.1	74.9 ± 4.1	11.4 ± 3.4	1.2 ± 0.7
Juveniles (42)	11.0 ± 3.7	13.7 ± 3.9	61.8 ± 5.9	13.4 ± 4.5	< 0.1 ± < 0.1
Males (48)	10.2 ± 3.2	9.3 ± 2.7	67.0 ± 5.1	12.4 ± 3.8	1.1 ± 0.8
Females (52)	4.8 ± 1.7	8.7 ± 2.5	72.6 ± 4.7	13.6 ± 4.2	0.3 ± 0.2
Year					
1992 (47)	7.3 ± 2.9	7.4 ± 2.4	79.1 ± 4.3[b]	5.5 ± 2.5[a]	0.7 ± 0.7
1993 (27)	13.5 ± 3.9	17.1 ± 4.9	63.7 ± 5.8[ab]	4.4 ± 1.7[a]	1.2 ± 1.2
1994 (19)	1.5 ± 0.9	9.4 ± 5.6	49.6 ± 10.0[a]	39.3 ± 9.8[b]	0.2 ± 0.1
1995 (9)	0	1.2 ± 1.0	74.9 ± 12.3[ab]	23.8 ± 12.3[ab]	< 0.1 ± < 0.1
Month					
May (9)	2.7 ± 1.8	2.5 ± 2.3	60.0 ± 13.6	34.5 ± 14.5[b]	0.2 ± 0.2
June (12)	4.2 ± 2.7	16.3 ± 7.1	54.3 ± 12.2	22.3 ± 11.4[ab]	2.8 ± 2.8
July (45)	10.6 ± 3.5	9.3 ± 3.3	67.5 ± 5.4	11.8 ± 3.8[ab]	0.7 ± 0.5
August (31)	6.0 ± 2.3	11.7 ± 3.5	78.5 ± 4.3	3.8 ± 1.6[a]	< 0.1 ± < 0.1
September (4)	0	0.6 ± 0.6	96.4 ± 3.4	2.8 ± 2.5[a]	0.3 ± 0.3

[1]Values with different superscripts within columns and category (habitat, age, sex, year, and month) differ at the 0.05 level (analysis of variance and Student-Newman-Keuls test after arcsine transformation, Zar 1974; fungi not included in ANOVA because of high frequency of zeros).
[2]Number of samples in parentheses. Totals vary because of occassional partial missing data about stomach source.

sponded to patterns in overstory tree dominants (Hanley and Hoel 1996), but the only statistically significant difference ($P < 0.05$) between habitat types was that Red Alder seed was most abundant in the alder floodplain forests.

Diet composition

Stomach contents were composed mostly of fruit and seed of understory plants during all years (69% overall), regardless of habitat type or age/sex class of mice (Table 5). Tree seed and leaf material were next most abundant (13 and 10%, respectively), while arthropods were least (7% overall). Only very minor amounts of fungi (< 1%) were observed in the stomach samples.

Univariate analysis of variance and Student-Newman-Keuls test (Zar 1974) indicated that composition of the stomach contents did not differ significantly ($P < 0.05$) between habitat or age and sex classes of mice. Minor differences occurred between years (fruit/seed greater in 1992 than 1994, and tree seed greater in 1994 than 1992). May samples contained more tree seed than did August and September samples.

Multivariate analysis of variance (Wilkinson et al. 1992) indicated no significant differences ($P < 0.05$) between habitat types, ages, or sexes. High consumption of tree seed in May and June of 1994 and 1995, however, resulted in significant differences among months and years.

Discussion

High-energy, readily digestible foods such as seeds and fruit appear to be most important and consistently preferred by *Peromyscus* mice (Vickery 1984; Vickery et al. 1994). Food preference and intake trials with Sitka Mice in our study area (Reese et al. 1997) indicated that Salmonberry and Stink Currant fruit and seeds were most highly preferred (voluntary intake) and valuable (body weight change) among fruits and that Sitka Spruce ranked highest among tree seeds.

Sitka Mice in our study area ate a diet composed mostly of fruit and seed throughout the trapping season (Table 5), which is consistent with results observed by Van Horne (1982b) for *P. maniculatus* in southeastern Alaska. Use of arthropods was low in comparison to diets reported for *P. maniculatus* elsewhere (Martell and Macaulay 1981; Wolff et al. 1985, but comparable to those of Van Horne 1982b) and did not differ by age classes as reported by Van Horne (1982b). Although fungi are often eaten by *P. maniculatus* (Rhoades 1986; Maser and Maser 1987; Cork and Kenagy 1989), they are frequently eaten in relatively low quantities, as observed in our study (Martell and Macaulay 1981; Van Horne 1982b; Wolff et al. 1985). Tree seed has been widely reported as an especially important winter and early spring food for *P. maniculatus* (Gashwiler 1979; Sullivan 1979; Halvorson 1982;

Wolff 1996), and that is also evident in our data from May and June (Table 5).

The lack of between-habitat differences in diet composition of Sitka Mice corresponds with the lack of between-habitat differences in food resources. The Beaver pond had the greatest species richness of understory plants and the greatest biomass of forbs and graminoids (Table 1) and, therefore, probably the greatest variety and production of understory seed. Total production of fruit, however, did not differ between habitat types, although species-specific differences did occur (Table 2). Given the low palatability of beetles (Reese et al. 1997), and low use of arthropods (Table 5), the lack of between-habitat differences in arthropod abundance (Table 3) is of little importance. Similarly, the relatively low use of tree seed during mid to late summer (Table 5) makes the few differences in seedfall (Table 4) relatively unimportant then.

Despite the great between-habitat differences in overstory (Hanley and Hoel 1996) and understory species composition (cluster analysis, above), therefore, the total food resources apparently differed very little between habitats, at least during the May-September periods of our study. This is not to say that food resources were unimportant; it says that food resources were more or less equivalent across habitats, and that floodplain forests provided neither better nor worse habitat for mice than did upland forests. Variation in food resources was evident in the between-year differences rather than between-habitat differences throughout our study area.

Habitat heterogeneity at the scale of broad habitat types, per se, does not appear to be an important factor affecting diet composition of Sitka Mice. However, heterogeneity at a finer scale (e.g., within-habitat microtopographic complexity: Pollock et al. 1998) must be important to mice through the production and availability of a wide variety of seeds, fruits, and other foods such as were widely available throughout the floodplains of our study area. The role of flooding may be especially critical to within-habitat heterogeneity, because it is flooding that rearranges the floodplain soils, creates back channels and ponds, opens the forest canopy along stream courses, and kills or nourishes plants of varying requirements and tolerances (Malonson 1993; Pollock et al. 1998). Spatial and temporal complexity within habitats, therefore, is an important feature of floodplain habitat in the production of food resources for mice.

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Literature Cited

Cork, S. J., and **G. J. Kenagy.** 1989. Rates of gut passage and retention of hypogeous fungal spores in two forest-dwelling rodents. Journal of Mammalogy 70: 512–519.

Cross, S. P. 1985. Responses of small mammals to forest riparian perturbations. Pages 269–275 *in* Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, April 16-18,1985, Tucson, Arizona. General Technical Report RM-120. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Farr, W. A., and **J. S. Hard.** 1987. Multivariate analysis of climate along the southern coast of Alaska: some forestry implications. Research Paper PNW-RP-372. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 38 pages.

Gashwiler, J. S. 1979. Deer mouse reproduction and its relationship to the tree seed crop. American Midland Naturalist 102: 95–104.

Goldsmith, F. B., and **C. M. Harrison.** 1976. Description and analysis of vegetation. Pages 85–155 *in* Methods in plant ecology. *Edited by* S. B. Chapman. John Wiley and Sons, New York.

Halvorson, C. H. 1982. Rodent occurrence, habitat disturbance, and seed fall in a larch-fir forest. Ecology 63: 423–433.

Hanley, T. A., and **W. W. Brady.** 1997. Understory species composition and production in old-growth western hemlock-Sitka spruce forests of southeastern Alaska. Canadian Journal of Botany 75: 574–580.

Hanley, T. A., and **T. Hoel.** 1996. Species composition of old-growth and riparian Sitka spruce-western hemlock forests in southeastern Alaska. Canadian Journal of Forest Research 26: 1703–1708.

Hansson, L. 1970. Methods of morphological diet micro-analysis in rodents. Oikos 21: 255–266.

Hogan, K. M., M. C. Hedin, H. S. Koh, S. K. Davis, and **I. F. Greenbaum.** 1993. Systematic and taxonomic implications of karyotypic, electrophoretic, and mitochondrial-DNA variation in *Peromyscus* from the Pacific Northwest. Journal of Mammalogy 74: 819–831.

Malonson, G. P. 1993. Riparian landscapes. Cambridge University Press, Cambridge, U.K. 296 pages.

Martell, A. M., and **A. L. Macaulay.** 1981. Food habits of deer mice (*Peromyscus maniculatus*) in northern Ontario. Canadian Field-Naturalist 95: 319–324.

Maser, C., and **Z. Maser.** 1987. Notes on mycophagy in four species of mice of the genus *Peromyscus*. Great Basin Naturalist 47: 308–313.

Nagorsen, D. W. 1990. The mammals of British Columbia: A taxonomic catalogue. Memoir Number 4, Royal British Columbia Museum, Vancouver. 140 pages.

Pielou, E. C. 1977. Mathematical ecology. John Wiley and Sons, New York. 385 pages.

Pollock, M. M. 1995. Patterns of plant species richness in emergent and forested wetlands of southeast Alaska. Ph.D. dissertation, University of Washington, Seattle. 219 pages.

Pollock, M. M., R. J. Naiman, and **T. A. Hanley.** 1998.

Plant species richness in riparian wetlands — a test of biodiversity theory. Ecology 79: 94–105.

Reese, E. O., J. C. Barnard, and **T. A. Hanley.** 1997. Food preference and *ad libitum* intake of wild-captured Sitka mice, *Peromyscus keeni sitkensis*. Canadian Field-Naturalist 111: 223–226.

Rhoades, F. 1986. Small mammal mycophagy near woody debris accumulations in the Stehekin River Valley, Washington. Northwest Science 60: 150–153.

Ruth, R. H., and **A. S. Harris.** 1979. Management of western hemlock-Sitka spruce forests for timber production. General Technical Report PNW-8. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 197 pages.

Sullivan, T. P. 1979. Repopulation of clear-cut habitat and conifer seed predation by deer mice. Journal of Wildlife Management 43: 861–871.

Van Horne, B. 1982a. Demography of the longtail vole *Microtus longicaudus* in seral stages of coastal coniferous forest, southeast Alaska. Canadian Journal of Zoology 60: 1690–1709.

Van Horne, B. 1982b. Niches of adult and juvenile deer mice (*Peromyscus maniculatus*) in seral stages of coniferous forest. Ecology 63: 992–1003.

Vickery, W. L. 1984. Optimal diet models and rodent food consumption. Animal Behaviour 32: 340–348.

Vickery, W. L., J.-L. Daoust, A. El Wartiti, and **J. Peltier.** 1994. The effect of energy and protein content on food choice by deer mice, *Peromyscus maniculatus* (Rodentia). Animal Behaviour 47: 55–64.

Wilkinson, L., M. Hill, J. P. Welna, and **G. K. Birkenbeuel.** 1992. SYSTAT for Windows: Statistics, version 5 edition. SYSTAT, Evanston, Illinois. 750 pages.

Wolff, J. O. 1996. Population fluctuations of mast-eating rodents are correlated with production of acorns. Journal of Mammalogy 77: 850–856.

Wolff, J. O., R. D. Dueser, and **K. S. Berry.** 1985. Food habits of sympatric *Peromyscus leucopus* and *Peromyscus maniculatus*. Journal of Mammalogy 66: 795–798.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey. 620 pages.

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The Consequences for Amphibians of the Conversion of Natural, Mixed-species Forests to Conifer Plantations in Southern New Brunswick

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We examined amphibian abundance and species richness in stands of natural, mixed-species forest and in a chronosequence of Black Spruce (*Picea mariana*) plantations up to 16-years old in southern New Brunswick, Canada, during 1993 and 1994. We studied seven species of amphibians in 64 terrestrial sites of 10+ ha, and at 16 ephemeral ponds. Eggs, larvae, and adult numbers were estimated using a variety of sampling methods (visual pond surveys, night calling, pit-fall traps, and searches of coarse-woody debris). The low abundance of woody angiosperm vegetation in conifer plantations, particularly those with incomplete canopy closure, resulted in less leaf litter and drier coarse-woody debris than in natural forest. Amphibians were more abundant in natural forest than in plantations of any age. The most common terrestrial amphibian in natural forest was the Redback Salamander (*Plethodon cinereus*; average density 4/100 m^2), but it occurred in only one of 33 plantations examined. Amphibians bred in all study ponds, including those in plantations, but only small numbers of American Toad (*Bufo americanus*), Yellow-spotted Salamander (*Ambystoma maculatum*), and Red-spotted Newt (*Notophthalmus viridescens*) were observed in terrestrial habitats of plantations outside of the breeding season. The densities of *A. maculatum* and Wood Frog (*Rana sylvatica*) breeding in ponds within plantations were most strongly related to the distance to the nearest natural forest. For Spring Peeper (*Pseudacris crucifer*) and *A. maculatum*, the high exposure and short hydroperiod of plantation ponds resulted in poor recruitment in both study years. Our study suggests that the conversion of natural, mixed-species forest into conifer plantations is most detrimental to *A. maculatum*, *P. cinereus*, *P. crucifer*, and *R. sylvatica*, and less-so for *B. americanus*.

Key Words: Salamanders, urodeles, frogs, anurans, eggs, larvae, metamorphosis, survivorship, forestry, coarse-woody debris, silviculture, New Brunswick.

Habitat loss through forest disturbance and conversions are suggested to be threatening populations of amphibians in many regions of North America (Blymyer and McGinnes 1977; Bury 1983; Pough et al. 1987; Ash 1988; Petranka et al. 1993). In Canada, almost one-million hectares of natural or semi-natural forest are harvested each year, mostly by clear-cutting, and most of this area is subsequently modified through silvicultural management (Anonymous 1995). Studies conducted in various places in North America indicate that clear-cutting can result in dramatic reductions or local extirpations of populations of amphibian species (Ash 1988; Bury and Corn 1988*a*, 1988*b*; Corn and Bury 1989; Wyman 1988; Dupuis et al. 1995).

Silvicultural practices that convert natural forest into plantations may also have an important influence on amphibians. In contrast to the predominantly coniferous forests of western and northern North America (where the effects of forestry on amphibians have been most intensively studied), forests in eastern Canada and the northeastern United States are often a mosaic of angiosperm-dominated, conifer-dominated, and mixed-species stands. Few studies have been made of the effects of clear-cutting and plantation establishment on amphibians in these eastern forests (for recent reviews see de Maynadier and Hunter 1995; Mitchell et al. 1997).

Here we report on a study of effects on amphibians of the conversion of natural, mixed-species forest into conifer plantations in the vicinity of Fundy National Park, in southern New Brunswick, Canada. Amphibian communities were assessed in stands of natural forest and in conifer plantations of various ages. Amphibian populations and activities were related to habitat in terms of: (1) the vegetation present in terrestrial habitats and breeding ponds; (2) abundance and quality of coarse-woody debris (CWD) and leaf litter; (3) ground-surface humidity and temperature; and (4) hydroperiod, water depth, and water quality of breeding ponds. Our goal was to determine how amphibian populations are affected by habitat changes associated with plantation establishment.

Methods

Study Area

We surveyed amphibian populations and habitats from March to September during 1993 and 1994. Terrestrial habitats and breeding ponds were studied in representative stands of natural, mixed-species forest and in conifer plantations (Black Spruce, *Picea mariana*) of various ages, up to 16-years old. All sites are located within the "Greater Fundy Ecosystem," comprised of Fundy National Park (FNP; 204 km^2; ca. 45°60'N, 65°00'W) and its surrounding landscape, much of which is intensively managed for forestry (Woodley and Freedman 1995; Woodley et al. 1998).

Each study site was categorized according to the time since the most recent stand-replacing disturbance, and by species composition of the dominant terrestrial vegetation. "Natural forest" was defined as mature, >80-year-old stands established by natural regeneration (stands were aged by coring dominant trees). Stands of natural forest occurred either as continuous forest in FNP, or as woodlots outside the park. There were three categories of Black Spruce plantations: open-canopy (4–5-year old stands at the time of our study), partial-canopy (8–9 years old), and closed-canopy (13–16 years old) (plantation stands were aged by counting rings in cross-sections or cores of dominant woody plants). All study sites were >10 ha in area and on similarly well-drained terrain on an extensive plateau, located about 250 m above sea level and approximately 20 km inland from the Bay of Fundy. A total of 64 terrestrial sites was selected for study, of which 34 were conifer plantations, including: 11 open-canopy sites, 10 partial-canopy sites, and 13 closed-canopy sites. Another 30 sites were stands of natural forest, located within FNP (n = 12) or in its surrounding landscape (n = 18).

Sixteen breeding ponds were studied within the terrestrial habitats described above. Ponds in natural forest were beneath a closed-canopy cover (n = 5), as were those in the closed-canopy plantations (n = 2). Ponds in partial- or open-canopy plantations were in exposed habitat (n = 9).

Amphibian Surveys

Terrestrial amphibians were surveyed in one 10 m × 10 m plot in each of 64 sites. The plot was randomly located within the site, but at a distance of >100 m from any major ecotone. Surveying occurred on days with high humidity following a rainfall event lasting >8 hours, when the surface litter and soil were moist and amphibian activity was high (Gibbons and Semlitsch 1981; Campbell and Christman 1982; Corn and Bury 1990; Dodd 1991). Search times were 5–10 person-hours per plot, depending on the abundance of CWD, litter, and rocks. In addition, to compare amphibian densities before and shortly after tree harvesting of one natural-forest stand outside FNP, searches were conducted in four 10 m × 10 m plots 10–18 days prior to clear-cutting in mid-June, 1994, and then 1, 4, 7, and 10 weeks after harvesting.

At 14 study sites, where additional habitat measurements were taken, further amphibian censusing was conducted using a grid of 16 pit-fall traps. The traps were 4-L plastic buckets arranged in a 4m × 4m grid (similar to trap-grids used by Corn and Bury 1991). Each grid was >100 m from any road, forest edge, or permanent waterbody. The pit-fall traps were visited at least every third day, from early May to the end of August (1993). Amphibian captures were standardized per 1000 trap-days.

Adults, egg masses, and larvae were sampled at the 16 aquatic sites. Abundance of breeding adults was estimated visually and from their calls during night-time surveys (22:00–23:00), on a weekly basis from early March until late August in 1993 and 1994. Surveys were done by 2–3 people, examining 10-m sections of shoreline habitat visually and acoustically. Assessment of reproduction included estimation of larval density bi-weekly from early May to late August, and direct observation of recently metamorphosed individuals (following Schaffer et al. 1994). Open-ended, fine-mesh quadrats of 30 cm × 30 cm were used to sample larvae at 5-m intervals within a 10–35 cm depth zone along the pond edges. Larvae were removed from the quadrats by repeated dip-netting, identified, counted, and released.

The direction of amphibian migration toward and away from six breeding ponds was studied in 1994. These ponds were located within open-canopy plantations, but within 40 m of natural forest. Drift-fences (1-m high and 25–35 m long) were installed along each pond, with one side facing the plantation interior and the other the nearby, natural forest. Fencing ran parallel to the long axis of the pond and extended 5 m beyond either end at a 60° angle. The fencing was constructed of wooden posts, 6–mil polyethylene sheeting, and 6-mm mesh hardware screening, with 11.4-L buckets buried at 5-m intervals on both sides. The drift-fences were checked for captured amphibians every three days from early April to early September.

Characteristics of Terrestrial Habitats

Selected microhabitat and microclimatic features were measured in habitats where amphibians were surveyed. Measurements in terrestrial habitats were: (1) plant cover, (2) dominant vegetation types, (3) abundance of leaf litter, (4) quantity and quality of CWD, (5) soil-surface temperature, and (6) relative humidity at ground level. Measurements in aquatic habitats were: (1) distance to the nearest natural forest, (2) hydroperiod, (3) water depth, (4) pond area, and (5) cover of aquatic vegetation.

The density, length, width, and quality (i.e., decay state; see Harmon et al. 1986) of CWD (diameter ≥5 cm) were measured in 10 m × 10 m plots at 48 of the 64 terrestrial sites. Decomposition stages were divided into five categories: (1) recently downed debris, (2) debris with loose bark, (3) moist debris with internal decay, (4) intensively decayed debris substantially integrated into the forest floor, and (5) dry woody debris. Additional habitat elements were measured at 14 sites, including five stands of natural forest and three stands of each of the three plantation categories. At each site, the cover of plants, exposed soil, and rocks (as percentage of the ground obscured) were estimated in 20-cm diameter quadrats (n = 16) located at >5-m intervals in random directions. These quadrats were also used to collect leaf litter on the ground surface, which was sorted into three categories (coniferous, graminoid, and dicotyledonous), dried, and weighed. Relative humidity was measured three times at the same sites using a manual psychrometer. Ground-surface temperature was recorded every two hours in one stand of each habitat category, using a recording thermograph placed under a log >25 cm in diameter.

Characteristics of Aquatic Habitats

The 16 study ponds were monitored in 1993 and 1994, from ice thaw in early spring until early September (by which time many of the ponds had dried up). In 1993, water samples were collected monthly from May to September and were analyzed for pH, colour, metals (Al, Fe, Pb), alkalinity, major ions (Ca, Mg, Na, K, SO_4, Cl), key nutrients (PO_4, NO_3, NH_4), and total organic carbon, by Environment Canada, Moncton, using standard methods (Environment Canada 1984). Physical characteristics of each pond were also described: i.e., maximum depth and surface area, presence of other ponds within 0.3 km, distance to nearest permanent aquatic habitat (such as a lake), distance to nearest forest edge and road, and pond hydroperiod (i.e., its persistence). Submerged and emergent macrophytes and the immediately surrounding terrestrial vegetation were also assessed, including the total cover and dominant species of plants.

Statistical Analyses

The amount and nature of CWD were compared among habitat types using nested or one-way ANOVA, where appropriate (Sokal and Rohlf 1981; Wilkinson 1990). The decomposition state of CWD in the 48 terrestrial sites was compared using Kruskal-Wallis rank-order analysis and Mann-Whitney U-tests. The significance of pair-wise comparisons was tested using a sequential Bonferroni correction to account for multiple comparisons (Wilkinson 1990). Shading of the ground surface and the quantity of leaf litter were compared between sites using Wilcoxin sign-rank tests and paired t-tests (Wilkinson 1990). Relative humidity at the ground surface was compared among sites using ANOVA.

Differences among habitat types were assessed for the presence/absence of amphibian species (Kruskal-Wallis rank-order analysis) and their abundance (Mann-Whitney U-tests with sequential Bonferroni significance tests; Sokal and Rohlf 1981; Wilkinson 1990). Egg-mass density was used as an indicator of the abundance of breeding Yellow-spotted Salamanders (*Ambystoma maculatum*) and Wood Frogs (*Rana sylvatica*) in ponds, while the relative abundance of other species was estimated from the number of breeding males. Larval densities were estimated using sampling data for the 10–35-cm depth zone, corrected for the pond area within the depth zone (Shaffer et al. 1994). Relationships among amphibian density (i.e., egg mass and larval density) and habitat variables (i.e., pond area, pond depth, pond shading, distance to natural forest, and percentage of pond containing aquatic vegetation) were analyzed using backward stepwise regression ($\alpha = 0.05$) and Pearson correlations (Sokal and Rohlf 1981). The data were normalized using square-root transformations (Sokal and Rohlf 1981), and relationships between amphibian density and habitat type were examined using regression analysis and Pearson correlations (Sokal and Rohlf 1981; Wilkinson 1990). Possible interactions between environmental variables were examined prior to regression analyses to ensure that variables were independent. The numbers of amphibians approaching or leaving drift-fenced ponds from the side facing the plantation or natural forest were compared among sites using a Wilcoxon Sign-Rank test (Wilkinson 1990).

Results

Characteristics of Terrestrial Habitats

The four classes of terrestrial habitats differed in the abundance of CWD and stumps ($p \leq 0.001$; Table 1). The density of identifiable CWD decreased with increasing age of plantations, while the density of stumps was more variable over time (Table 1). The state of wood decay differed among the three age-categories of plantations (Table 1). Almost all CWD in open- and partial-canopy plantations was either recently deposited or was dry throughout (decay stages 1 and 5, respectively; Harmon et al. 1986). In contrast, CWD in closed-canopy plantations was typically in later stages (decay stages 3–4) of decomposition ($p \leq 0.001$), and included minimal amounts of dry debris (i.e., stage 5). The stands of natural forest and the closed-canopy plantations had wood in various stages of decomposition, although most of their CWD was in later stages of decay (stages 3–4).

The abundance, distribution, and composition of leaf litter differed among the habitat types. Angiosperm tree litter was only present in appreciable quantities in stands of natural forest, and this component significantly increased the overall abundance of litter (average 2.5 kg/m^2, of which

TABLE 1. Density, decay state, and diameter of coarse-woody debris (per 100 m^2; average ± S.E.) in conifer plantations and natural forest.

Stand type	Density	Decay state	Diameter
Open-canopy plantation			
Logs (n = 33)	4.5 ± 1.5^{p}	$1.0 \pm 1.0^{p,c,m}$	$13.5 \pm 7.0^{c,m}$
Stumps (n = 109)	15.5 ± 11.0	$0.5 \pm 1.0^{p,c,m}$	$44.0 \pm 25.5^{c,m}$
Partial-canopy plantation			
Logs (n = 65)	$9.0 \pm 6.0^{o,c,m}$	$1.0 \pm 1.5^{o,c,m}$	$15.5 \pm 7.0^{c,m}$
Stumps (n = 210)	$30.0 \pm 15.0^{c,m}$	$1.0 \pm 1.5^{o,c,m}$	$26.0 \pm 16.5^{c,m}$
Closed-canopy plantation			
Logs (n = 22)	3.0 ± 2.0	$3.5 \pm 0.5^{o,p,m}$	$17.0 \pm 14.0^{o,p}$
Stumps (n = 83)	12.0 ± 5.0^{p}	$3.5 \pm 1.0^{o,p,m}$	$28.0 \pm 17.0^{o,p}$
Natural forest			
Logs (n = 27)	3.5 ± 1.0	$3.5 \pm 4.5^{o,p}$	$17.5 \pm 8.0^{o,p}$
Stumps (n = 89)	11.5 ± 4.0^{p}	$3.0 \pm 0.5^{o,p,c}$	$34.5 \pm 17.0^{o,p}$

For each pairwise comparison (t-tests with sequential-Bonferroni correction), superscripts indicate significant differences from values for open-canopy plantations (o), partial-canopy plantations (p), closed-canopy plantations (c), and natural, mixed-species forest (m).

2.3 kg/m^2 was litter of woody angiosperms) relative to the plantations (overall average of 0.32 kg/m^2; $p < 0.05$). The quantity of coniferous litter in natural forest was similar to that in closed-canopy plantations ($p > 0.05$), but the natural forest also had much larger amounts of woody-angiosperm litter, which significantly increased the overall abundance of litter relative to those plantations ($p < 0.05$).

Percentage plant cover and the dominant plant species differed greatly among site categories (Veinotte 1998; Veinotte and Freedman 1998). Consistent with the definitions of our habitat categories, stands with closed canopies, both natural-forest and plantation, provided the most shade (average percent cover of 83% and 77%, respectively), and cover was significantly higher in these stands than in clear-cuts or open- or partial-canopy plantations ($p < 0.05$). The average cover of partial-canopy plantations (59%) provided less shading than the closed-canopy stands (77%), but more than in open-canopy plantations or clear-cuts (48% and 41%, respectively). Foliar cover in plantations with incomplete canopy closure did not differ from that of clear-cuts ($p > 0.05$).

The ground-surface temperature fluctuations in the plantation sites, even under a closed canopy, were greater than in the natural-forest sites. For example, peak temperatures in early May and June reached 28°C in the plantations, but were less than 20°C in the natural forest.

The stands of natural forest had higher relative humidity at the ground surface (62-84%; measured in midsummer) than occurred in the plantations. The ranges of relative humidity were similar among the open-, partial-, and closed-canopy plantations (51–55%, 51–57%, and 54–67%, respectively), and were similar to that in recently clear-cut areas (51–57%).

Amphibian Populations in Terrestrial Habitats

Stands of natural forest had significantly more amphibians in the 10m × 10m search plots than did any of the plantations (Table 2; $p < 0.04$). Within natural forest, 29 of 30 search plots contained amphibians (93%), compared with 5 of 34 plots (15%) in plantations. Of the five plantations containing amphibians in search plots, four were closed-canopy plantations. The amphibians found in plantations were Red-spotted Newt (*Notophthalmus viri-*

TABLE 2. Density of amphibians found in searches of 10 m × 10 m plots in five habitat types. Data are in no./100 m^2; average ± S.E.; total captures are given in brackets.

Species	Natural forest	Plantations		
		Open-canopy	Partial-canopy	Closed-canopy
	(30 sites)	(11 sites)	(10 sites)	(13 sites)
Plethodon cinereus	4.0 ± 0.5 (116)	0.0	0.0	0.1 ± 0.1 (1)
Ambystoma maculatum	0.4 ± 0.1 (9)	0.0	0.0	0.3 ± 0.1 (3)
Notophthalmus viridescens	0.0	0.0	0.0	0.1 ± 0.1 (1)
Pseudacris crucifer	<0.1 (1)	0.0	0.0	0.2 ± 0.1 (2)
Rana sylvatica	0.1 ± 0.1 (3)	0.0	0.0	0.1 ± 0.1 (1)
Bufo americanus	0.2 ± 0.2 (6)	0.1 ± 0.1 (1)	0.0	0.2 ± 0.1 (2)

TABLE 3. Captures of amphibians in pit-fall traps in natural forest and three age-classes of conifer plantations. Data were collected from early May to the end of August, 1993, and are expressed as no./1000 trap-days, mean ± S.D.; total captures per species per habitat are given in brackets. Only abundant species are reported here.

Species	Natural forest	Plantations: Open canopy	Plantations: Partial canopy	Plantations: Closed canopy
Ambystoma maculatum	5.8 ± 0.3 (35)	2.0 ± 0.0 (8)	0.0	0.0
Notophthalmus viridescens	2.5 ± 0.4 (15)	0.0	0.0	0.0
Bufo americanus	1.2 ± 0.5 (7)	7.7 ± 0.6 (31)	5.8 ± 0.9 (23)	5.8 ± 1.0 (23)
Pseudacris crucifer	1.2 ± 0.5 (7)	0.0	0.0	0.0
Rana sylvatica	4.6 ± 0.3 (28)	0.0	0.0	0.0

descens; efts only), American Toad (*Bufo americanus*; found once in an open- and once in a closed-canopy plantation), and Red-back Salamander (*Plethodon cinereus*; found in one closed-canopy plantation). In contrast, *P. cinereus* was the most common amphibian species in the natural forest, occurring in 92% of the plots searched. The mean density of *P. cinereus* in natural forest inside FNP (i.e., 4.5/plot) was similar to that of natural-forest fragments outside FNP (4.3/plot; one-tailed t-test, $p = 0.4$).

Outside of the breeding season, adult salamanders were primarily encountered in stands of natural forest, although a few individuals occurred in closed-canopy plantations in association with large, moderately decayed logs and stumps (decay stages 2–4). *Notophthalmus viridescens* and *A. maculatum* were found in closed-canopy stands (plantation and natural forest). *Plethodon cinereus* was most commonly associated with CWD in decay stages 2 or 3, but it also occurred in mixed-species leaf litter in natural forest. The density of *P. cinereus* was monitored at one natural-forest site prior to clear-cutting, and then for 10 weeks afterwards. Prior to the harvest there was an average of 2.5/100 m^2, but no *P. cinereus* were observed during sampling occurring 1, 4, 7, and 10 weeks after the clear-cutting.

The most common species in pit-fall traps in natural forest were *A. maculatum* and *R. sylvatica*, both of which were uncommon or absent in plantations outside of their breeding season (Table 3). Only *B. americanus* were regularly caught in plantation habitats, where their abundance exceeded that in natural forest.

Amphibian Terrestrial Activity

Amphibian captures at the drift-fenced ponds were greatest in traps facing the natural-forest sides (forested: n = 122 captures of 7 species; plantation n = 44 captures of 5 species; Table 4). About twice as many adults were captured on the forested side of the ponds than on the plantation side (n = 64 and 34, respectively). For *A. maculatum*, most of the adult captures were made during the first two weeks of their breeding period (27/33). Of the total captures of this species, most (25/33) occurred in traps facing natural forest ($p = 0.04$). For *B. americanus* (14/17) and *R. sylvatica* (26/26), most adult captures, prior to and during the breeding season, were made in traps facing natural forest. For both of these species and *A. maculatum*, fences facing the plantations only began

TABLE 4. Average number of amphibians captured over three months in drift-fence traps at four study ponds, on the side facing natural forest or open-canopy plantation. Data are average captures ± S.E. Only abundant species are reported here.

Species	Adults	Juveniles*	Total
Rana sylvatica			
forest side	6.8 ± 6.5	4.1 ± 5.4	10.9 ± 10.0
plantation side	4.0 ± 3.9	1.0 ± 1.4	5.0 ± 4.9
Bufo americanus			
forest side	3.0 ± 2.3	4.6 ± 2.4	7.6 ± 3.8
plantation side	2.5 ± 1.2	1.6 ± 0.9	4.1 ± 1.0
Ambystoma maculatum			
forest side	4.6 ± 1.8	0.0	4.6 ± 1.8
plantation side	1.6 ± 1.0	0.0	1.6 ± 1.0

*juveniles were defined as individuals smaller than half the maximum adult snout-vent length.

to trap amphibians after breeding was complete (i.e., when animals were migrating back to terrestrial habitat). Juvenile amphibians encountered in the drift-fence traps included *R. sylvatica* and *B. americanus*, both of which were captured more frequently in traps facing natural forest (31/38 and 28/37, respectively; $p = 0.07$ and 0.04, respectively).

At one of the six drift-fenced ponds, 57 adult *P. cinereus* were captured, nearly half of them (22/57) on a single day (May 27), which was the first warm, rainy day (maximum air temperature 10° C) after a prolonged dry, cool period in the springtime. Subsequent captures during that growing season at that site continued at rates of up to 2 individuals/day, for a total of 35 additional captures. This site was located about 500 m from an area of natural forest that had been clear-cut just before winter, eight months before the beginning of our study. The captures at this single pond comprised 95% of all captures of *P. cinereus* at drift-fences. *Ambystoma maculatum* was also caught in relatively large numbers at this pond (n = 15). The capture patterns for both *P. cinereus* and *A. maculatum* at this pond contrast with captures at the other ponds. The difference was most pronounced for *P. cinereus*, which was caught only three times at the other five ponds. Because of these anomalous data, which are apparently related to mass emigration from the recently clear-cut habitat, captures at this pond were excluded from further comparative analyses of the drift-fence data. The toad *B. americanus* was the most consistently active species in our study. Both adults and juveniles were active in all terrestrial habitats, from just after snowmelt through the growing season. In contrast, captures of *R. sylvatica* were greatest during the breeding period (n = 40); 20 of the 24 subsequent captures occurred on the plantation side of the drift fences (13 of the 24 captures were of recently metamorphosed juveniles).

Water Chemistry

Chemical analyses of water from the ponds indicate that all variables measured were within reported tolerance limits for amphibians (Saber and Dunson 1978; Freda and Dunson 1984; Gascon and Planas 1986). With the exception of one plantation pond (pH 7.2–7.5), all aquatic habitats were moderately acidic ($5.3 \geq$ pH ≥ 6.5). One partial-canopy pond and one open-canopy pond differed from the other ponds in water chemistry, having more extreme values for dissolved organic carbon, phosphorous, nitrate, chloride, conductivity, and colour. A cluster analysis of ponds based on average water chemistry values resulted in small euclidian distances, indicating that the ponds are rather similar with respect to chemical attributes. When water chemistry-derived clusterings were compared with groupings based on habitat class or amphibian density, no obvious patterns were apparent.

Amphibian Activities in Aquatic Habitats

The four most commonly encountered amphibian species in aquatic habitats were *B. americanus, R. sylvatica,* Spring Peeper (*Pseudacris crucifer*), and *A. maculatum*; eggs of one or more of these species were present in 90% of the study ponds. These species have larvae that metamorphose within one growing season. Species with larvae that overwinter (i.e., Bullfrog, *Rana catesbeiana* and Green Frog, *R. clamitans*) were present as "adults" (i.e. arbitrarily defined as individuals 50% or greater in snout-vent length for maximum size of the species) at 60% of the ponds, but larvae of these species were rarely observed (<5% of ponds). There was significant variability in the densities of breeding adults of *P. crucifer* and *R. sylvatica* at breeding ponds ($p < 0.05$; Kruskal-Wallis rank-order test), but these differences could not be attributed to habitat type ($p > 0.05$; Mann-Whitney U-test).

Metamorphosing juvenile *A. maculatum* and *P. crucifer* were found beneath cover objects in the immediate proximity of breeding ponds, beginning in the latter part of July. Large numbers of pre-metamorphic larvae and recently metamorphosed juveniles that were either dead or dying of desiccation were found in the basins of aquatic habitats that dried before all juvenile amphibians had completed metamorphosis. This was observed in late summer (August to September) at 11 of the 16 study ponds in 1993, and in 16 of 22 ponds in 1994. Most of the ponds that dried in 1993 and 1994 were in plantations (81% and 87%, respectively), although 40% of ponds in natural forest also dried during the two study years.

Amphibian-Habitat Relationships

Strong relationships were observed between certain environmental variables and densities of *A. maculatum, R. sylvatica* and *P. crucifer*. In both study years, the density of egg masses of *R. sylvatica* was negatively correlated with the closest distance to natural forest ($r = -0.51$, $p = 0.046$ in 1993; $r = -0.43$, $p = 0.10$ in 1994). A stepwise backward regression of the density of *A. maculatum* egg masses in ponds relative to habitat features indicated that the distance to natural forest had the strongest influence ($r^2 = 0.39$, $p < 0.006$). Adjusting the egg-mass data for pond surface area did not alter this result for *A. maculatum*. The distance to natural forest did not appear to be a factor influencing the abundance of *P. crucifer* larvae at the ponds. Instead, pond surface area correlated most strongly with their abundance ($r = 0.76$, $p = 0.001$ in 1993; $r = 0.63$, $p = 0.009$ in 1994). However, in 1994, pond depth was also positively correlated with *P. crucifer* larval density ($r = 0.56$, $p = 0.023$).

The feature of the aquatic habitats that accounted for most variability in egg-mass and larval density differed among species. For *A. maculatum*, 49% of the variability in larval density was attributable to pond persistence and percent cover of submerged vegetation (regression analysis; $p < 0.016$). For both *R. sylvatica* and *P. crucifer*, pond hydroperiod, the amount of pond shading, and the cover of submerged vegetation collectively accounted for 15% of the observed variability in larval density, although this relationship was not significant ($p > 0.05$).

Discussion

Harvesting and conversion of natural forest into conifer plantations is extensive in North America (Petranka et al. 1993; Freedman 1995). In New Brunswick, more than 91 000 ha of natural forest are harvested each year, mostly by clear-cutting, and about 18% of that area is re-planted with conifers and managed as plantations (Anonymous 1995). Our results suggest that amphibians are being detrimentally affected by this conversion of natural forests into conifer plantations. The main factors affecting amphibians are differences in microclimate and microhabitat between conifer plantations and natural forests (Harman et al. 1986).

Amphibians in Terrestrial Habitats

Microclimatic conditions (i.e., relative humidity and surface temperature) and the quality and quantity of microhabitat elements (i.e., leaf litter, CWD, and plant cover) differ greatly between conifer plantations and natural, mixed-species forest (Harman et al. 1986; Fleming and Freedman 1998; Veinotte and Freedman 1998). Ash (1995, 1997) observed that leaf-litter quantity and moisture content can be significantly reduced following clear-cutting. Immature spruce plantations have climatic conditions similar to those of clear-cuts, because sparse, incomplete shading subjects the ground surface to intense insolation and large fluctuations in daily temperature. In a recent, landscape-scale study of amphibians at 160 ponds in Ontario, Hecnar and M'Closkey (1998) found that the amount of regional woodland was the single most important variable correlating with amphibian species richness. Our study supports this observation.

The species-poor tree composition of plantations also reduces the quantity and diversity of leaf litter and CWD, particularly that of angiosperm trees and shrubs. The paucity of structural complexity in terms of canopy cover, litter, and CWD in plantations, and the exposure to wind and insolation, reduce humidity at the ground surface below conditions occurring in mature, natural forest, causing CWD to become dry and brittle (deMaynadier and Hunter 1998). Only after the plantation canopy closes does the CWD retain moisture and become similar in quality to that in the natural forest. However, the intensive management and subsequent clear-cut harvesting of plantations greatly reduces the potential for future inputs of large-dimension woody debris (Freedman et al. 1996; Fleming and Freedman 1998) that provides critical microhabitat for terrestrial amphibians. Overall, these changes in microclimate and microhabitat result in conditions that are unfavourable to many species of amphibians occurring in natural forest (for recent reviews, see deMaynadier and Hunter 1995, 1998).

Ash (1995) found that litter mass, depth, and moisture content all decreased for two years following a clear-cut harvest in North Carolina. The rate of recolonization by plethodontid salamanders was correlated with the rate at which litter re-accumulated (Ash 1997). Similarly, we found that the highest abundance and species richness of amphibians occurred in habitats with the most leaf litter, ground cover, CWD, and highest humidity. Most use of plantation habitats by adult amphibians is seasonal, particularly the use of aquatic breeding sites. Amphibians occurring in plantations outside of the breeding season were locally restricted to small areas with relatively moderate microenvironments. The one plantation that supported *P. cinereus* was also the only one where some mature angiosperm trees had been left standing (see also Mitchell et al. 1997). A sparse availability of habitat refuges (i.e., litter, CWD, and shade) and microclimatic extremes (i.e., high daily surface temperature and low relative humidity), as was observed in our conifer plantations, reduces foraging time and increases the risk of desiccation for terrestrial amphibians (Heatwole 1961; Maiorana 1978; Jaeger 1980; Diller and Wallace 1994; Dupuis et al. 1995; Gabor and Jaeger 1995). These are likely the key factors restricting the use of plantation habitats by most terrestrial amphibians.

In fact, microclimatic extremes in the plantations appear to have exceeded the known tolerance of some amphibian species, notably *A. maculatum* and *P. cinereus* (Waldick 1997). *Ambystoma* species, particularly as juveniles, require a forest floor in which the organic matter contains 45–65% moisture (Parmelee 1993). In the open-canopy plantations, we observed ground-surface temperatures during the summer that exceeded the critical upper threshold (32° C) of *A. maculatum* (Pough and Wilson 1977). *Plethodon cinereus* also prefers moist substrates and moderate temperatures (5–25° C; Taub 1961). *Rana sylvatica* similarly requires moderate temperatures (15–20° C) and relative humidity above 70% (Heatwole 1961). These tolerances can be exceeded in plantations in southern New Brunswick during the summer.

Leaf litter and CWD must be moist to be used as refuge or foraging habitat by amphibians (Jaeger 1980; Mathis 1990; Elliott et al. 1993; Parmelee 1993; Dupuis et al. 1995; Gabor and Jaeger 1995). *Plethodon* is especially dependent on moist woody debris, which they use for deposition and incubation sites for their eggs, and as overwintering refugia

(Burton and Likens 1975; Jaeger 1980; Sinsch 1990; Frisbie and Wyman 1992; Blaustein et al. 1994; deMaynadier and Hunter 1995; Mitchell et al. 1997). Many of the amphibian species in our study area (e.g., *A. maculatum P. crucifer, P. cinereus,* and *R. sylvatica*) were commonly observed beneath moist leaf litter and within the moist interior of woody debris; these are critical microhabitats for these species.

A variety of suitable microhabitats within a heterogeneous forest floor increases the diversity and abundance of invertebrate prey available for amphibians (Olson 1963; Burton and Likens 1975; Douglas 1981; Elliott et al. 1993) and thereby provides lucrative foraging habitat. *Plethodon* salamanders are predators of litter invertebrates, and were only found in the one plantation studied that had residual clusters of mature, angiosperm trees. The quality of leaf litter at this site appears to have enabled these salamanders to persist after the clear-cutting and planting of conifers (although they could also have been subsequent immigrants from nearby, intact natural forest).

Soil pH levels <4 have been shown to exceed the acidity tolerance of *P. cinereus* (Frisbie and Wyman 1992; Wyman and Jancola 1992). Inputs of acidic litter in spruce plantations and natural spruce forests commonly result in pH values below 4. Because of a lack of relatively base-rich angiosperm litter, the acidic forest floor of spruce plantations provides poor habitat for this species.

The presence of a few *A. maculatum* in closed-canopy plantations, and the occurrence of *P. cinereus* in one of these sites, suggests that even small mixed-species patches that include angiosperm trees can provide suitable terrestrial microhabitat for salamanders (Clawson et al. 1997). However, most plantations established in our study area during the past two decades are intensively managed to decrease the abundance of hardwood trees, for example, through the silvicultural use of herbicides. Consequently, the poor quality of refuge and foraging habitat is a serious constraint on the use of plantation habitats by amphibians.

Amphibians in Aquatic Habitats

Some adult amphibians travel as far as 1 km through terrestrial habitat to reach breeding ponds (e.g., Bellis 1962; Sinsch 1990; Licht 1991; Blaustein et al. 1994). Our study suggests that adults of *A. maculatum, B. americanus,* and *R. sylvatica* approach ponds in plantations from nearby (within about 400 m) intact, natural forest. The limited dispersal distances of these species may be due to the risks of predation and/or desiccation while migrating through exposed habitats in open- and partial-canopy plantations. Elsewhere, adult *Ambystoma* are known to be philopatric to their breeding pond, and to re-use routes to and from a pond (Stenhouse 1985). The low numbers of immigrants from the direction of plantations in our study suggests that the density of *A. maculatum* is low in those terrestrial habitats.

Differences have been noted in the use of microhabitats by adult and juvenile salamanders (Loredo et al. 1996). Adults are more resistant to desiccation than juveniles, enabling them to travel greater distances and to inhabit drier microenvironments. Juveniles, particularly when recently metamorphosed, are less successful in locating favourable microhabitats, perhaps due to inexperience and an inability to travel long distances. In exposed habitats, therefore, survivorship of recently metamorphosed salamanders and other amphibians is typically low because they are so vulnerable to predation and desiccation (Spotila 1972; Shoop 1974; Stenhouse 1987; Semlitsch et al. 1988; Sinsch 1990). Juvenile mortality was high in the plantation ponds in this study, because many young amphibians were unable to complete metamorphosis, or to find suitable refuge habitat after leaving their natal pond.

In our study area, the density of temporary ponds is greater in clear-cuts and young plantations than in natural forest. This is because dug-outs and gravel pits created during road building fill with water. DeMaynadier and Hunter (1997) also noted that "many forest management practices incidentally create artificial breeding depressions..." but that "research is needed to evaluate the reproductive success of species colonizing these sites." We have observed that only ponds in closed-canopy sites contained submerged or emergent macrophytic vegetation. Until the overhead canopy closes, plantation ponds are highly exposed and experience warm temperatures and high rates of evaporation. Thus, even though the artificial ponds in plantations and clear-cuts can be of similar size and depth to ephemeral ponds in natural forest, they typically have a much shorter hydroperiod.

The abbreviated hydroperiod of most plantation ponds in our study proved lethal for larvae of *P. crucifer* and *A. maculatum*. In both study years, amphibian larvae and recent metamorphs suffered massive mortality during August or early September, as a result of early pond drying in the open- or partial-canopy plantations. Only those individuals able to deposit their eggs early enough to ensure that their larvae metamorphosed before August had reproductive success at these ponds. Initially, the presence of amphibian eggs at the artificially created ponds in plantations suggested that the ponds might benefit local amphibians. However, premature drying of these ponds undermined the potential benefits for most breeding amphibians during our study. In a similar vein, Hecnar and M'Closkey (1998) found a strong positive correlation between vegetation cover, which retards pond evaporation, and amphibian species richness in ponds in Ontario.

In the relatively exposed plantations, dispersal distances from natal ponds are frequently too great to allow dispersing juveniles to reach hospitable, forested environments (see also Dodd and Cade 1998). In view of the observation that juvenile *Ambystoma jeffersonianum* only travel about 100 m from their natal pond after metamorphosis (Parmelee 1993), it seems unlikely that many juvenile salamanders could travel up to >400 m through open plantation habitats to reach more humid, natural-forest habitat in our study area. Recently metamorphosed larvae can experience high mortality, from desiccation and predation (Spotila 1972; Shoop 1974; Stenhouse 1987; Semlitsch et al. 1988; Sinsch 1990; Rowe and Dunson 1995; Wassersug 1997), and these are critical stresses during late summer in open-canopy plantations. We conclude that artificial ponds in clear-cuts and open-canopy plantations attract breeding adult amphibians, but there is only a small chance of successful metamorphosis and safe migration of their offspring out of these aquatic habitats.

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Literature Cited

Anonymous. 1995. Selected Forestry Statistics. Information Report E-X-47. National Research Council, Canadian Forest Service, Ottawa.

Ash, A. N. 1988. Disappearance of salamanders from clear-cut plots. Journal of the Elisha Mitchell Science Society 104: 116–122.

Ash, A. N. 1995. Effects of clear-cutting on litter parameters in the Southern Blue Ridge Mountains. Castanea 60: 89–97.

Ash, A. N. 1997. Disappearance and return of plethodontid salamanders to clear-cut plots in the Southern Blue Ridge Mountains. Conservation Biology 11: 983–989.

Bellis, E. D. 1962. The influence of humidity on wood frog activity. American Midland Naturalist 68: 139–148.

Blaustein, A. R., D. B. Wake, and **W. P. Sousa.** 1994. Amphibian declines: Judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology 8: 60–71.

Blymyer, M. J., and **B. S. McGinnes.** 1977. Observations on possible detrimental effects of clear-cutting on terrestrial amphibians. Bulletin of the Maryland Herpetological Society 13: 79–83.

Burton, T. M., and **G. E. Likens.** 1975. Energy flow and nutrient cycling in salamander populations in the Hubbard brook experimental forest, New Hampshire. Ecology 56: 1068–1080.

Bury, R. B. 1983. Differences in amphibian populations in logged and old-growth Redwood forests. Northwest Science 57: 167–178.

Bury, R. B,. and **P. S. Corn.** 1988a. Douglas-Fir forests in the Oregon and Washington Cascades. Relation of the herpetofauna to stand age and moisture. Pages 11–22 *in* Management of amphibians, reptiles, and small mammals in North America. *Edited by* R. C. Szaro, K. E. Severson, and D. R. Patton. U.S.D.A. Forest Service, General Technical Report RM-166.

Bury, R. B., and **P. S. Corn.** 1988b. Responses of aquatic and streamside amphibians to timber harvest: a review. Pages 165–185 *in* Streamside Management: Riparian Wildlife & Forestry Interactions. Volume 59. *Edited by* J. K. Raedeke. Institute for Forest Resources, University of Washington.

Campbell, H. W., and **S. P. Christman.** 1982. Field techniques for herpetofaunal community analysis. Pages 193–217 *in* Herpetological Communities. *Edited by* N. J. Scott Jr. United States Department of the Interior, Fish and Wildlife Service, WRP 13.

Clawson, R. G., B. G. Lockaby, and **R. H. Jones.** 1997. Amphibian responses to helicopter harvesting in forested floodplains of low-order, blackwater streams. Forest Ecology & Management 90: 225–235.

Corn, P. S., and **B. Bury.** 1989. Logging in western Oregon: Responses of headwater habitats and stream amphibians. Forest Ecology & Management 29: 39–57.

Corn, P. S., and **B. Bury.** 1990. Sampling methods for terrestrial amphibians and reptiles. A. B. Carey and L. F. Ruggiero *in* Wildlife-habitat Relationships: Sampling procedures for Pacific Northwest Vertebrates. *Edited by* U.S.D.A. Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report, PNW-GTR-256.

Corn, P. S., and **B. Bury.** 1991. Terrestrial amphibian communities in the Oregon Coast Range. Pages 305–317 *in* Wildlife and Vegetation of Unmanaged Douglas-fir Forest. *Edited by* L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff. U.S.D.A. Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report, PNW-GTR-285.

deMaynadier, P. G., and **M. L. Hunter, Jr.** 1995. The relationship between forest management and amphibian ecology. A review of the North American literature. Environmental Reviews 3: 230–261.

deMaynadier, P. G. and **M. L. Hunter, Jr.** 1998. Effects of silvicultural edges on the distribution and abundance of amphibians in Maine. Conservation Biology 12: 340–352.

Diller, L. V., and **R. L. Wallace.** 1994. Distribution and habitat of *Plethodon elongatis* on managed, young growth forests in North Coastal California. Journal of Herpetology 28: 310–318.

Dodd Jr., C. K. 1991. Drift fence-associated sampling bias of amphibians at a Florida Sandhills temporary pond. Journal of Herpetology 25: 296–301.

Dodd Jr., C. K., and **B. S. Cade.** 1998. Movement patterns and the conservation of amphibians breeding in small, temporary wetlands. Conservation Biology 12: 331–339.

Douglas, M. E. 1981. A comparative study of the topographical orientation in *Ambystoma*. Copeia 1981: 460–463.

Dupuis, L. A., J. N. M. Smith, and **F. Bunnell.** 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. Conservation Biology 9: 645–653.

Environment Canada. 1984. NAQUADAT Dictionary of Parameter Codes. Water Quality Branch, Environment Canada, Moncton, New Brunswick.

Elliot, W. M., N. B. Elliot, and **R. L. Wyman.** 1993. Relative effects of litter and forest type on rate of decomposition. American Midland Naturalist 129: 87–95.

Fleming, T. L., and **B. Freedman.** 1998. Conversion of natural, mixed-species forests to conifer plantations: Implications for dead organic matter and carbon storage. Ecoscience 5: 213–221.

Freda, J., and **W. A. Dunson.** 1984. Sodium balance of amphibian larvae exposed to low environmental pH. Physiological Zoology 57: 435–443.

Freedman, B. 1995. Environmental ecology. The impacts of pollution and other stresses on ecosystem structure and function. Academic Press, San Diego, California.

Freedman, B., V. Zelanzny, D. Beaudette, T. Fleming, S. Flemming, G. Forbes, G. Johnson, and **S. Woodley.** 1996. Biodiversity implications of changes in the quantity of dead organic matter in managed forest. Environmental Reviews 4: 238–265.

Frisbie, M. P., and **R. L. Wyman.** 1992. The effect of soil chemistry on sodium balance in the red-backed salamander: A comparison of two forest types. Journal of Herpetology 26: 434–442.

Gabor, C. R., and **R. G. Jaeger.** 1995. Resource quality affects the agnostic behaviour of terrestrial salamanders. Animal Behaviour 49: 71–79.

Gascon, C., and **D. Planas.** 1986. Spring pond water chemistry and the reproduction of the wood frog *Rana sylvatica*. Canadian Journal of Zoology 64: 543–550.

Gibbons, J. W., and **R. D. Semlitsch.** 1981. Terrestrial drift fences with pitfall traps: An effective technique for quantitative sampling of animal populations. Brimleyana **7**: 1–16.

Harmon, M. E., J. F. Franklin, F. J. Swanson, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper, K. Cromack, Jr., and **K. W. Cummins.** 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15: 133–302.

Heatwole, H. 1961. Habitat selection and activity of the woodfrog, *Rana sylvatica*. American Midland Naturalist 66: 301–313.

Hecnar, S. J. and **R. T. M'Closkey.** 1998. Species richness patterns of amphibians in southwestern Ontario. Journal of Biogeography 15: 763–772.

Jaeger, R. G. 1980. Fluctuations in prey availability and food limitation for a terrestrial salamander. Oecologia 44: 335–341.

Licht, L. E. 1991. Habitat selection of *Rana pipiens* and *Rana sylvatica* during exposure to warm and cold temperatures. American Midland Naturalist 125: 259–268.

Loredo, I., D. Van Vuren, and **M. L. Morrison.** 1996. Habitat use and migration behaviour of the California tiger salamander. Journal of Herpetology 30: 282–285.

Maiorana, V. C. 1978. Behaviour of an unobservable species: Diet selection by a salamander. Copeia 1978: 664–672.

Mathis, A. 1989. Do seasonal spatial distributions in a terrestrial salamander reflect reproductive behavior or territoriality? Copeia 1989: 788–791.

Mitchell, J. C., S. C. Rinehart, J. F. Pagels, K. A. Buhlmann, and **C. A. Pague.** 1997. Factors influencing amphibian and small mammal assemblages in central Appalachian forests. Forest Ecology & Management 96: 65–76.

Olson, J. S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44: 322–331.

Parmelee, J. R. 1993. Microhabitat segregation and spatial relationships among four species of mole salamanders (Genus *Ambystoma*). Occasional Papers of the Museum of Natural History of Kansas 160: 1–33.

Petranka, J. W., M. E. Eldridge, and **K. E. Haley.** 1993. Effects of timber harvesting on Southern Appalachian salamanders. Conservation Biology 7: 363–370.

Pough, F. H., and **R. E. Wilson.** 1977. Acid precipitation and reproductive success of *Ambystoma* salamanders. Water, Air, and Soil Pollution 7: 307–316.

Pough, F. M., E. M. Smith, D. M. Rhodes, and **A. Collazo.** 1987. The abundance of salamanders in forest stands with different histories of disturbance. Forest Ecology and Management 20: 1–9.

Rowe, C. L., and **W. A. Dunson.** 1995. Impacts of hydroperiod on growth and survival of larval amphibians in temporary ponds in central Pennsylvania. Oecologia 102: 397–403.

Saber, P. S., and **W. A. Dunson.** 1978. Toxicity of bog water to embryonic and larval anuran amphibians. Journal of Experimental Zoology 204: 33–42.

Semlitsch, R. D., D. E. Scott, and **J. H. K. Pechmann.** 1988. Time and size at metamorphosis related to adult fitness in *Ambystoma talpoideum*. Ecology 69: 184–192.

Shaffer, H. B., R. A. Alford, B. D. Woodward, S. J. Richards, R. G. Altig, and **C. Gascon.** 1994. Quantitative sampling of amphibian larvae. Pages 130–141 *in* Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. *Edited by* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. Smithsonian Institute Press, Washington.

Shoop, C. R. 1974. Yearly variation in larval survival of *Ambystoma maculatum*. Ecology 55: 440–444.

Sinsch, U. 1990. Migration and orientation in anuran amphibians. Ethology, Ecology, and Evolution 2: 65–79.

Sokol, R. R., and **F. J. Rohlf.** 1981. Biometry. 2nd edition Freeman, San Francisco, California.

Spotila, J. R. 1972. Role of temperature and water in the ecology of lungless salamanders. Ecological Monographs 42: 95–125.

Stebbins, R. C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Co., Boston.

Stenhouse, S. L. 1985. Migratory orientation and homing in *Ambystoma maculatum* and *Ambystoma opacum*. Copeia 1985: 631–637.

Stenhouse, S. L. 1987. Embryo mortality and recruitment of juveniles of *Ambystoma maculatum* and *Ambystoma* *opacum* in North Carolina. Herpetologica 43: 496–501.

Taub, F. B. 1961. The distribution of the red-backed salamander, *Plethodon c. cinereus*, within the soil. Ecology 42: 681–698.

Veinotte, C. 1998. A comparative analysis of plant communities in natural, mixed-species forests and silvicultural plantations within the Greater Fundy Ecosystem, New Brunswick. M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

Veinotte, C., and **B. Freedman.** 1998. Plant biodiversity in natural, mixed-species forests and plantations in the vicinity of Fundy National Park. Pages 81–83 *in* State of the Greater Fundy Ecosystem. *Edited by* S. Woodley, G. Forbes, and A. Skibicki. Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, New Brunswick.

Waldick, R. C. 1997. Effects of forestry practices on amphibian populations in eastern North America. Herpetological Conservation 1: 191–205.

Wassersug, R. 1997. Assessing amphibian populations from the larval perspective. Herpetological Conservation 1: 271–281.

Wilkinson, L. 1990. SYSTAT: The system for statistics. SYSTAT, Inc., Evanston, Illinois.

Woodley, S. and **B. Freedman.** 1995. The Greater Fundy Ecosystem Project. A case study in ecosystem management. The George Wright Forum 12: 7–14.

Woodley, S., G. Forbes, and **A. Skibicki.** *Editors.* 1998. State of the Greater Fundy Ecosystem. Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, New Brunswick.

Wyman, R. L. 1988. Soil acidity and moisture and the distribution of amphibians in five forests of southcentral New York. Copeia 1988: 394–399.

Wyman, R. L., and **J. Jancola.** 1992. Degree and scale of terrestrial acidification and amphibian community structure. Journal of Herpetology 26: 392–401.

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A New Application of the Adaptive-Kernel Method: Estimating Linear Home Ranges of River Otters, *Lutra canadensis*

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Standard techniques for estimating size of home range for semiaquatic mammals usually result in overestimating area because unused tracts of land and water are incorporated into calculations. For River Otters (*Lutra canadensis*) that inhabited a narrow strip of habitat along the terrestrial-marine interface, linear length of shoreline previously was used as a measure of home-range size. Although that method produced a conservative estimate, selection of data points using that procedure did not provide any measure of probability or indication of core areas. We used the adaptive-kernel estimator and Geographic Information System (GIS) for calculating linear length of home ranges for River Otters inhabiting a marine environment and assessed the effect of reducing the bandwidth size on those home-range estimates. Using locations collected from four otters in Ester Passage, Prince William Sound, Alaska, USA, during summer 1991, we determined that adaptive kernel with 100% and 95% density contours resulted in a larger estimate than that produced by the previously used method. Decreasing bandwidth did not significantly alter the estimated linear distances of home range. In addition, the use of density contours of 65% delineated core areas; therefore, this technique provided a tool with which researches can to test hypotheses such as seasonal shifts in size and location of home ranges in relation to resource availability and distribution. Our technique may be useful for estimating home ranges of other animals approximating a linear distribution of locations.

Key Words: River Otter, *Lutra canadensis*, adaptive kernel, GIS, home range, Alaska.

The size and location of a home range on the landscape, and the distribution of resources within, are important factors in the management and conservation of many species of wildlife (Kantola and Humphry 1990; Schonewald-Cox et al. 1991; Mladenoff et al. 1995; Gomez de Silva Garza 1996; Sherry and Holmes 1996; Weaver et al. 1996). All the techniques for describing home ranges treat animal movements as two-dimensional data (Worton 1989; White and Garrott 1991; Samuel and Fuller 1994; Kie et al. 1996; Seamen and Powell 1996). This multi-dimensionality in turn may create a problem when animal movements are primarily unidimensional (i.e., limited to a narrow strip of habitat). For semiaquatic mammals such as River Otters (*Lutra canadensis*), American Mink (*Mustela vison*), Water Shrews (*Sorex palustris*), Beavers (*Castor canadensis*), and Muskrat (*Ondatra zibethicus*), describing home ranges using existing techniques (e.g., minimum convex polygon, bivariate normal, harmonic mean, fixed kernel, or conventional adaptive kernel; Worton 1989; White and Garrott 1991; Seamen and Powell 1996) usually results in overestimation of home-range size because unused tracts of land and water are incorporated into the calculation.

We encountered the problem of a unidimensional distribution of animal locations during our analysis of home ranges of River Otters in marine environments following the Exxon Valdez Oil Spill (Testa et al. 1994; Bowyer et al. 1995). Home ranges of River Otters and European Otters (*Lutra lutra*) have been described in terms of linear lengths of shoreline because these mustelids inhabit a narrow strip of habitat along a terrestrial-marine interface (Woolington 1984; Testa et al. 1994; Bowyer et al. 1995; Kruuk 1995). Bowyer et al. (1995) described home ranges of otters from oiled and nonoiled areas in terms of lengths of shoreline measured between locations of radio-tracked otters. To eliminate extreme data points, Bowyer et al. (1995) arbitrarily required that any given location be 1 km from the nearest location of that same otter, and that there were at least two locations on the same shore or island for inclusion of points in the calculation of home-range length. Although that method produced a conservative and repeatable estimate, a measure of probability or indication of core areas was not provided. In European Otters living in coastal environments, the spatial organization into a group-range system was dependent on such core areas, which represented the patchy distribution of food resources (Kruuk and Moorhouse 1991; Kruuk 1995).

The adaptive-kernel method estimates home ranges of an individual animal using a bivariate probability distribution by fitting a kernel-shaped function around locations of that animal (Worton, 1989; Kie et al. 1996; Seamen and Powell 1996).

TABLE 1. Estimates of linear home ranges length (km) for four River Otters in Esther Passage, Prince William Sound, Alaska, USA, during summer 1991. Home range lengths were calculated in GIS (ARC/INFO) using adaptive kernel (CALHOME) and the method described by Bowyer et al. (1995).

Otter ID		Home-range length (km)				
	Density Contour:	100%	95%	80%	65%	Bowyer*
	Bandwidth Size (%)					
1511 (male)	Default[a]	15.55	12.13	8.16	7.81	8.67
	90	15.08	12.16	8.19	8.09	
	80	14.75	12.09	8.06	7.99	
1781 (male)	Default[a]	10.19	9.88	7.79	7.68	9.81
	90	10.09	9.80	7.66	7.51	
	80	9.97	9.90	7.50	7.35	
1821 (male)	Default[a]	25.29	13.72	10.44	5.13	8.70
	90	24.96	13.51	10.35	5.07	
	80	24.72	13.51	10.34	4.89	
1640 (female)	Default[a]	12.27	11.98	11.65	10.81	7.97
	90	11.77	11.57	10.93	10.55	
	80	11.27	11.11	10.39	9.75	

*Method used by Bowyer et al. (1995).
[a]Bandwidth automatically calculated by CALHOME.

This technique allows the fitting of a model that incorporates differing proportions of home-range use based on locations (e.g., 95%, 80%, 65% probability contours), and thereby provides identification of core areas (i.e., zones of greater use). Unlike other methods of home-range estimation, adaptive kernel does not make assumptions about the statistical distribution (i.e., is nonparametric), is not restricted by assumptions of normality, and can have more than one core area (Worton 1989, 1995; Kie et al. 1996). We described the use of adaptive kernel and GIS for estimating linear (nearly unidimensional) home ranges of coastal River Otters, and compared our results from that analysis with those obtained from the method presented by Bowyer et al. (1995).

Estimates of home-range size produced by the adaptive-kernel method can be sensitive to the bandwidth size (i.e., the width of the kernel) or the smoothing parameter (i.e., the fit of a probability function that is used in creating the probability countour; Worton 1989, 1995; Kie et al. 1996). The program CALHOME estimates a default bandwidth as well as the appropriate smoothing parameter, assuming a normal distribution of animal locations. In instances when the assumption of normality is not met, the default smoothing parameter can be inappropriate and result in an overestimation of the home-range size (Seamen and Powell 1996). In such an instance, the least-squares cross validation (LSCV) score (the difference between the unknown true-density function and the kernel-density estimate) can be minimized by changing the bandwidth, thereby decreasing the estimated error associated with the calculated home range (Kie et al. 1996). Usually, when locations of animals are clumped rather than normally distributed, reduction of bandwidth results in lower LSCV scores, representing better fit of those data. Therefore, we also assessed the effect of reducing the bandwidth size on estimates of linear home ranges of River Otters along coastline habitats.

Study Area

Data on locations of River Otters were collected in Esther Passage, Prince William Sound, Alaska, USA (161°30′N, 147°40′W) from June to August 1991. The area has a maritime climate; summers are cool and wet, and winters are characterized by deep snow (220 cm annual precipitation). Higher elevations are typified by alpine tundra, and low elevations by old-growth forest (primarily *Tsuga heterophylla* and *Picea sitchnsis*) with well-developed understory (mainly *Vaccinium*, *Menziesia*, and *Rubus*). Alder (*Alnus*) tends to occur on disturbed sites, and near the boundary of terrestrial vegetation and the intertidal zone. Shorelines are steep and rocky with numerous inlets, bays, and coves. More detailed descriptions of the study area were provided by Bowyer et al. (1994, 1995) and Ben-David et al. (1996).

Methods

In summer 1990, River Otters were live-trapped with Hancock traps (Hancock Trap Company, Hot Springs, South Dakota) from May to the end of June. After immobilization, the captured otters were surgically implanted with radio-transmitters (Telonics, Mesa, Arizona) by a licensed veterinarian (for more details see Duffy et al. 1993, 1994; Rock et al. 1994; Testa et al. 1994; Bowyer et al. 1995). After recovery, animals were released near their site of capture. The life of transmitters was approximately 24 months, allowing tracking of otters well into summer

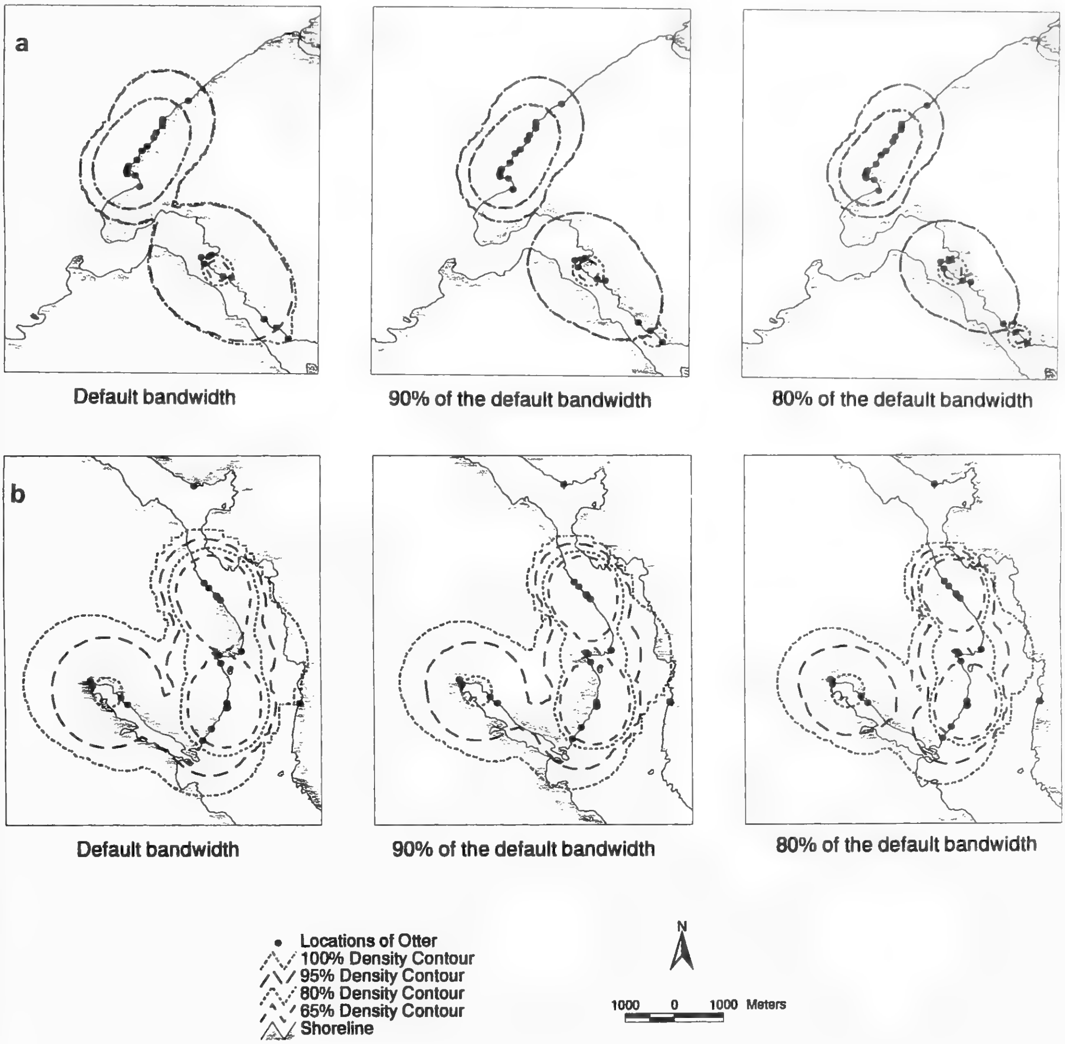

FIGURE 1. Examples of delineation of home ranges of two River Otters (a. 1781, b. 1821) calculated from field locations collected in Esther Passage, Prince William Sound, Alaska, during summer 1991 using CALHOME and GIS. Shaded areas represent land. For each otter, four different density contours for three values of bandwidth were plotted. Linear lengths of home ranges were calculated by measuring the length of coast between the points where the density contours intersect the shoreline. Note the exclusion of the eastern shore of Esther Passage in the home-range estimation for otter 1821 (b) between 100% and 95% contours.

1991. Throughout that summer, seven of the radio-implanted otters were located from a skiff and were followed continuously for 24 h from a distance ≥10 m. We obtained a sufficient sample for four otters to estimate home-range size, determined by the asymptotic relation between home-range size and number of locations. Groups of otters were located opportunistically as we maneuvered the skiff along the shoreline every other day. Once a group was located, the focal animal in each observation bout was selected randomly. The locations of the otters were plotted on a US Geological Survey topographical map (1: 63 500) every time the focal animal was detected visually. Data for four of the animals (three males: $n = 22$, 36, 24 locations; and one female: $n = 16$ locations) were included in our analysis of home ranges.

Home-range Analysis

Locations of otters along the shoreline were digitized from field maps into a Geographical Information System, GIS (ARC/INFO, Redlands,

TABLE 2. P-values from Wilcoxon paired-sample test comparing the effects of bandwidth size on calculation of linear shoreline lengths of home ranges of four River Otters in Esther Passage, Prince William Sound, Alaska, USA, during summer 1991. Linear lengths were determined by ARC/INFO using input from CALHOME with default, 90% of default, and 80% of default bandwidth sizes.

	Density Contours			
	100%	95%	80%	65%
Default vs 90% of default	0.068	0.144	0.144	0.465
90% vs 80% of default	0.068	0.273	0.068	0.068

California), and aligned (i.e., justified) to the coastline of a coverage of Prince William Sound. The amended points constituted the Cartesian coordinates in CALHOME (Kie et al. 1996). We used the adaptive-kernel method with a grid-cell size (the number of cells into which the study area is divided) of 50 by 50 cells to ensure that the computed contours would closely approximate those data (Kie et al. 1996). Based on our previous knowledge of the distribution of an otter within its home range (Bowyer et al. 1995), we selected density contours that encompassed areas representing 100%, 95%, 80%, and 65% of the locations. Those contours were entered onto the GIS map and the linear length of shoreline was measured between the points of intersection of the contours and the shoreline (a protocol for the transfer between GIS and CALHOME is available from M. Ben-David). We used the length of shoreline rather than the area contained within a contour to avoid the bias of including large areas of land and water where an otter did not occur. If a single contour (e.g., 65%) consisted of more than one polygon, we assumed that an otter used the shoreline between the polygons, and included that distance in the calculation of its linear home range. For comparison, we also used the GIS program to calculate shoreline length (home range) for the identical data set using the method described by Bowyer et al. (1995). We tested whether bandwidth had an effect on the estimation of linear home ranges by using the default bandwidth calculated by CALHOME, and then comparing those results with ones we obtained from 90% and 80% of the default value.

Statistical Analysis

We used a one-tailed Wilcoxon paired-sample test (Zar 1984; SPSS for Windows) to examine differences between the lengths of home ranges from the adaptive kernel and the conservative method used by Bowyer et al. (1995) for the same data set we obtained during summer 1991. We also used this same analysis to test for the effects of bandwidth on the home-range estimations.

Results

Estimates of linear home ranges originating from adaptive-kernel analysis with 100% ($P = 0.034$) and 95% ($P = 0.034$) density contours with default bandwidths were significantly larger than the estimates obtained from the method described by Bowyer et al. (1995; Table 1). Estimates of shoreline lengths with 80% ($P = 0.36$) and 65% ($P = 0.23$) from the adaptive-kernel model, however, were not significantly larger than estimates made from the method of Bowyer et al. (1995; Table 1). For otter 1821, the large reduction of in home-range length between 100% and 95% density contours was a result of exclusion of the eastern shore of Esther Passage from that calculation (Table 1; Figure 1b). Similarly, For both otters 1511 and 1821, linear length declined by a factor of two and a factor of five, respectively (Table 1; Figure 1b), between 100% and 65% density contours as a result of exclusion of a long and narrow cove (Shoestring Cove; Figure 1b) from the calculation. We did not detect a significant difference between the length of linear home range using the default, 90%, and 80% bandwidths for any of the density contours (i.e., 100%, 95%, 80%, or 65%; Table 2).

Discussion

An adaptive-kernel analysis is sensitive to autocorrelation among observations and home-range size is underestimated when samples are not independent (Kie et al. 1996). Although our data sets were autocorrelated, we retained all data points because sample sizes (i.e., number of locations per otter) were not large, and because we used this same procedure in calculating home-range length as described by Bowyer et al. (1995). Our analysis indicated that using adaptive kernels with 100% and 95% density contours resulted in a larger estimate of home-range length than did the method of Bowyer et al. (1995). That outcome indicated that the latter was more equivalent to the results of 80% and 65% density contours. Any bias in our 95% contours, because of autocorrelation or small sample size, would underestimate home-range size, yet those estimates were far less conservative than the method described by Bowyer et al. (1995).

The reduction of bandwidth did not significantly change the estimation of length of home ranges with our modification of the adaptive-kernel method (Table 2). Therefore, we suggest that use of default bandwidth will result in a reliable estimate for most linear home ranges. That outcome may not hold when identifying core areas of concentrated use (e.g., 65% contours) because the lengths of patches of resources may be much shorter than 2 km (which is the maximum distance in which the two methods differed for that contour; Table 1). Kruuk (1995) demonstrated that sections of about 90 m of shoreline differ significantly in their algal cover and in the diving behavior of the European Otters along the coast of Shetland, United Kingdom.

Our estimates of the length of home ranges for summer 1991, based on the method of Bowyer et al. (1995), were lower than those described by Bowyer et al. (1995) for the same otters in the previous summer (1990). In addition, we did not detect a difference between the estimate of home-range lengths for the female and three males (Table 1). Those outcomes were likely a result of the different methods used to sample the locations of otters between studies. Bowyer et al. (1995) obtained radiolocations by surveying the shoreline on a fixed route with a small skiff and via aerial telemetry, whereas we used data that were collected from otters only during visual observations. Thus, our samples were less likely to include points from the extreme ends of the study area. That difference, however, had little effect on our conclusions because the same bias (i.e., same data set from 1991) was present in both methods we compared (Table 1).

The use of adaptive-kernel method, combined with the GIS for calculating lengths of home ranges for River Otters provided an estimator with an associated measure of probability (i.e., density contours), and also identified potential core areas. That outcome provided an additional advantage over the method previously described by Bowyer et al. (1995) because identifying core areas will allow researchers to concentrate efforts of measuring prey availability in those sections of the home range extensively used by otters. Moreover, our new methodology will allow direct comparisons of home-range length, where use of areas is inappropriate. Home ranges of River Otters in coastal environments differed between sexes, age groups, and reproductive status of otters (Woolington 1984; Bowyer et al. 1995; Kruuk 1995). Therefore, use of our new technique will allow tests of hypotheses such as seasonal shifts (summer vs. winter) in size and location of core areas in relation to resource availability and distribution. Our goal of developing a method that would allow such comparisons was met. In addition, the method we proposed may be useful to quantify home ranges of other animals with near-linear distributions.

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Literature Cited

Ben-David, M., R. T. Bowyer, and **J. B. Faro.** 1996. Niche separation by mink and river otters: coexistance in a marine environment. Oikos 75: 41–48.

Bowyer, R. T., W. J. Testa, J. B. Faro, C. C. Schwartz, and **J. B. Browning.** 1994. Changes in diets of river otters in Prince William Sound, Alaska: effects of the Exxon Valdez Oil Spill. Canadian Journal of Zoology 72: 970–976.

Bowyer, R. T., J. W. Testa, and **J. B. Faro.** 1995. Habitat selection and home ranges of river otters in a marine environment: effects of the *Exxon Valdez* Oil Spill. Journal of Mammalogy 76: 1–11.

Duffy, L. K., R. T. Bowyer, J. W. Testa, and **J. B. Faro.** 1993. Differences in blood haptoglobin and length-mass relationships in river otters (*Lutra canadensis*) from oiled and nonoiled areas in Prince William Sound, Alaska. Journal of Wildlife Diseases 29: 353–359.

Duffy, L. K., R. T. Bowyer, J. W. Testa, and **J. B. Faro.** 1994. Chronic effects of the Exxon Valdez Oil Spill on blood and enzyme chemistry of river otters. Environmental Toxicology and Chemistry 13: 643–647.

Gomez de Silva Garza, H. 1996. The conservation importance of semiendemic species. Conservation Biology 10: 674–675.

Kantola, A. T., and **S. R. Humphry.** 1990. Habitat use by Sherman's fox squirrel (*Sciurus niger* Sherman) in Florida. Journal of Mammalogy 71: 411–419.

Kie, J. G., J. A. Baldwin, and **C. J. Evans.** 1996. CALHOME: a program for estimating animal home ranges. Wildlife Society Bulletin 24: 342–344.

Kruuk, H. 1995. Wild Otters. Oxford University Press. Oxford, United Kingdom.

Kruuk, H., and **A. Moorhouse.** 1991. The spatial organization of otters (*Lutra lutra* L.) in Shetland. Journal of Zoology, London 224: 41–57.

Mladenoff, D. J., T. A. Sickley, R. G. Haight, and **A. P. Wyddeven.** 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. Conservation Biology 9: 274–294.

Rock, K. R., E. S. Rock, R. T. Bowyer, and **J. B. Faro.** 1994. Degree of association and use of a helper by coastal river otters, *Lutra canadensis*, in Prince William Sound, Alaska. Canadian Field-Naturalist 108: 367–369.

Samuel, M. D., and **M. R. Fuller.** 1994. Wildlife radiotelemetry. Pages 370-418 *in* Research and management techniques for wildlife and habitats. *Edited by* T. A. Bookhout. The Wildlife Society, Betheda, Maryland, USA.

Schonewald-Cox, C., R. Azari, and **S. Bluma.** 1991. Scale, variable density, and conservation planning for mammalian carnivores. Conservation Biology 5: 491–495.

Seamen, D. E., and **R. A. Powell.** 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77: 2075–2085.

Sherry, T. W., and **R. T. Holmes.** 1996. Winter habitat quality, population limitation, and conservation of neotropical-nearctic migrant birds. Ecology 77: 36–48.

Testa, J. W., D. F. Holleman, R. T. Bowyer, and **J. B. Faro.** 1994. Estimating populations of marine river otters in Prince William Sound, Alaska, using radiotracer implants. Journal of Mammalogy 75: 1021–1032.

Weaver, J. L., P. C. Paquet, and **L. F. Ruggiero.** 1996. Resilience and conservation of large carnivores in the Rocky mountains. Conservation Biology 10: 964–976.

White, G. C., and **R. A. Garrott.** 1991. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

Woolington, J. D. 1984. Habitat use and movements of river otters at Kelp Bay, Baranof Island, Alaska. M.S. thesis, University of Alaska Fairbanks. Fairbanks, Alaska, USA.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164–168.

Worton, B. J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. The Journal of Wildlife Management 59: 794–800.

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, New Jersey, USA.

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Surface Activity and Structure of a Hydrothermally-heated Maternity Colony of the Little Brown Bat, *Myotis lucifugus*, in Alaska

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In north-temperate environments reproductive bats require access to warm, sheltered roosts to raise young successfully. In Southeast Alaska cool temperatures and persistent rain and fog may limit the availability of suitable natural maternity roosts. Heated man-made structures provide shelter for most known bat nurseries. We describe the structure, thermal environment, and surface activity of the first documented non-commensal maternity colony of *Myotis lucifugus* in Alaska. This colony of over 450 bats is uniquely located at a hydrothermally-heated roost beneath coastal beach boulders on Chichagof Island in Southeast Alaska. The importance of hydrothermal refuges in determining bat distribution in this region is discussed.

Key Words: Little Brown Bat, *Myotis lucifugus*, maternity colony, hot springs, rainforest, Southeast Alaska.

Climate and the availability of roosts are often major factors that determine the distribution and activity of bats in northern regions (Humphrey 1975; Kunz 1982; Bell et al. 1986; Thomas 1988; Nagorsen and Brigham 1993; Parker et al. 1997). Cold and inclement weather not only reduce the availability of flying insects used as food (Racey and Swift 1981), but impose high energy demands for thermoregulation (Studier and O'Farrell 1972; McNab 1982; Kurta 1986; Kurta et al. 1989). To conserve energy under these conditions bats often enter daily torpor (McNab 1982; Hamilton and Barclay 1994; Vonhof and Barclay 1997). For males, who do not share the costs of reproduction, torpor provides an efficient means for reducing daily energy expenditures (Wang and Wolowyk 1988). For pregnant and lactating females, however, torpor can reduce rates of fetal and juvenile development and potentially jeopardize juvenile survival by delaying the opportunity to develop sufficient fat reserves for migration and hibernation (Racey and Swift 1981; Kunz 1982; Kurta et al. 1989). To optimize fetal and neonatal development, reproductive females must maintain high body temperatures and establish maternity colonies in warm, sheltered roosts (McNab 1982).

North American vespertilionid bats are well known for their use of caves for roost sites (Barbour and Davis 1969), but they also roost in many other natural and artificial structures if environmental conditions are favorable (Kunz 1982). Tree hollows, spaces under bark or in foliage, stumps, rock crevices, buildings, abandoned mines, and bridges are all used by bats for roosts (Barbour and Davis 1969; Fenton 1983; Barclay and Cash 1985; Christy and West 1993; Hamilton and Barclay 1994; Vonhof and Barclay 1996, 1997). Pregnant and lactating females commonly congregate in maternity colonies in tree hollows or in the attics of buildings where high summer temperatures favor rapid growth of the young (Davis and Hitchcock 1965; Schowalter et al. 1979; Barclay and Cash 1985; Nagorsen and Brigham 1993). Rarely, nursery colonies have been found in roosts heated by natural hot springs (Firman et al. 1992; Nagorsen and Brigham 1993).

Much of the north Pacific coast of North America is an active geothermal area with numerous hot springs (Motyka and Moorman 1983), but little is known about the ecological importance of these sites for bats (Parker et al. 1997). Three hydrothermally-heated maternity colonies have been described in British Columbia. Firman et al. (1992) described a colony of Keen's Bats (*Myotis keenii*) located beneath coastal beach boulders on Hot Springs Island (Gaandl Kin) in the Queen Charlotte Islands. Hot water (46°C) from this spring also heats a nursery colony of Little Brown Bats (*M. lucifugus*) in a nearby rock crevice. Nagorsen and Brigham (1993) described a colony of *M. lucifugus* in a small cave on the Grayling River in northern British Columbia. This roost is maintained at a constant 30°C by a small hot spring. Here we report on a maternity colony of *M. lucifugus* at a hydrothermally-heated roost on the outer coast of Chichagof Island in Southeast Alaska. Like the Gaandl Kin colony in the Queen Charlotte Islands, this roost is located beneath coastal beach boulders.

Study Area

The roost was on the beach 60 m inland from the ocean in a small cove at White Sulfur Hot Springs (57°48′35″N, 136°20′42″W), 112 km northwest of Sitka. Bats entered and left the roost through small openings between the boulders within an area of approximately 15 m^2. Two hot springs issued from fissures in the bedrock at the edge of the forest 10 m inland from the roost entrance. Both springs produced streams of hot water that flowed down the beach under the boulders to the ocean. The largest of these springs has been contained in a concrete pool for recreational use and is covered by a wooden shelter. The second spring formed a small pool approximately 20 m east of this building. The bat colony was heated by runoff from the second spring. Surface water temperatures at this spring averaged 42.0 ± 2.6°C ($\bar{x}$ ± s.d., n = 5) during this study. Within the roost, stream temperatures averaged 25.6 ± 2.4°C (n = 10). Daily outside ambient air temperatures ranged between 11° and 16°C.

Methods

On 23, 24, and 25 July 1992 we mist-netted bats as they exited and re-entered the roost. Two 6 m nets were set up along the eastern and southern borders of the roost entrance. Bats emerged from the roost by flying vertically from the beach. They then briefly circled the entrance before flying inland to the forest. Upon returning, the bats circled the entrance before landing on beach boulders next to openings to the roost. They then crawled into the roost. Individual bats were captured as they circled the entrance. Bats captured on 23 and 24 July were banded with numbered plastic forearm split-rings (Barclay and Bell 1988). We estimated colony size using a modified Lincoln-Peterson index (Serber 1982) for mark-recapture studies based on recapture data obtained on 25 July. We recorded the time of capture, sex, weight, and reproductive status of each bat captured. Lactating and post-lactating females were identified by the presence of enlarged nipples and bare patches around the nipples (Racey 1988). All bats were released immediately after they were measured and banded.

Results

We captured a total of 133 bats (80 females, 53 males). Sixty-eight of these were banded (51 females, 17 males), nine of which (5 females, 4 males) were re-captured. Twenty-six (48%) of the females captured on 24 and 25 July were lactating or in post-lactating condition. These data were not collected on 23 July. The total number of bats in the colony was estimated to be 461 individuals. This estimate is conservative because only adults and volant young emerged from the colony. Younger, nonflying bats that remained in the roost could not be counted.

The first bats emerged from the roost at approximately 2150 h (18 min after sunset) each night. Females tended to emerge first (Figure 1). Males showed a general increase in activity until 2330 h, a gradual decrease until 0130 h, then a marked increase at dawn. Females were most active at emergence, 0130 h, and at dusk. Throughout the night more females were captured than males until approximately 0330 h, when the number of males captured exceeded that of females until dawn. Several individual females were recaptured multiple times during the night. One female (#13) was recaptured at 1111 h, 0225 h, and 0301 h. Another female (#14) was recaptured at 0049 h and 0227 h. No males were recaptured at any time during the night except during their return to the roost just before sunrise. The last bats entered the roost at approximately 0450 h (20 min before sunrise). During each night of this study the bats remained active even during light intermittent rain.

Discussion

The large size of the White Sulfur Hot Springs colony indicates that this hydrothermally-heated roost is ecologically important for bats in this region. The warm temperatures of the roost provide a thermal environment highly favorable for raising young. Studies of the thermoregulatory capacity of *M. lucifugus* suggest the thermal neutral zone for pregnant females lies approximately between 32°C and 38°C (Sturdier and O'Farrell 1972; Burnett and August 1981). While we were not able to measure the temperatures directly next to bats within the roost, the temperatures of the heated water (42°C) and air above the stream (26°C) bracket this thermal neutral range. Bats roosting on rocks directly heated by the water, or in small crevices above pools of hot water, are likely to experience thermal conditions close to, if not within their thermal neutral zone. By comparison, daily outside ambient temperatures at White Sulfur Hot Springs ranged between 16°C and 21°C below the presumptive lower critical temperature (32°C) for pregnant females of this species. This warmer roost environment would allow pregnant and lactating females to maintain high body temperatures without the added energetic costs of thermoregulation that would be required in nonheated roosts, energy that can be more profitably directed toward reproduction.

The presence of adult males at the roost suggests that they may derive thermal benefits from the area as well, particularly during the day. In more southern latitudes, adult male *M. lucifugus* typically occupy day roosts away from the nurseries (Fenton and Barclay 1980), alone or in small groups. The temperatures at these locations are generally cooler than the nurseries and the bats commonly enter torpor to conserve energy. At White Sulfur Hot Springs, the warm

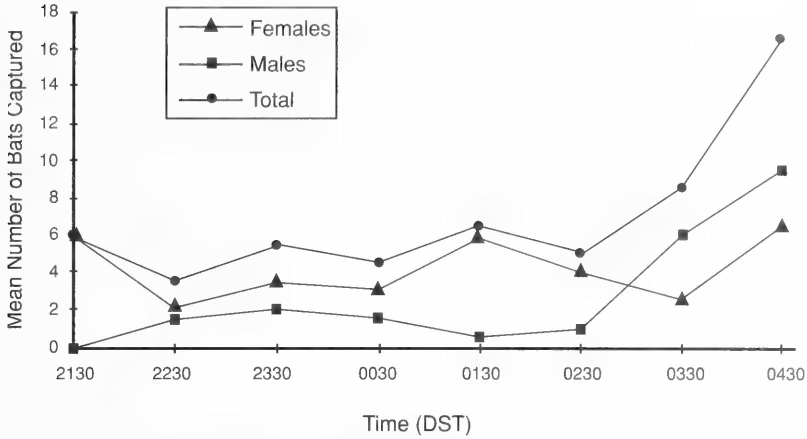

Figure 1. Mean number of *Myotis lucifugus* captured per hour at White Sulfur Hot Springs, Chichagof Island, Southeast Alaska, 23 –25 July 1992.

environment of the maternity roost may offset daily thermoregulatory costs more effectively than torpor would in nonheated tree or cavity roosts. This adaptive strategy could occur if the energetic costs of arousal from torpor in nonheated roosts were greater than the costs of not entering torpor, or of entering shallow torpor (e.g., to 26°C), in the hot springs roost. In natural roosts of drier interior environments, Little Brown Bats commonly select day roosts with southwestern exposures where solar heating provides exogenous heat for arousal from torpor (Fenton 1970; also see Vonhof and Barclay 1997). In Southeast Alaska persistent rain and fog can preclude solar heating as a source of regular, dependable heat. Under these conditions it may be energetically more efficient for males not to use unheated natural roosts, but to seek shelter during the day in the warm environment of the hydrothermally-heated maternity colony.

While limited, our capture data also suggest that male bats at White Sulfur Hot Springs may not use the maternity roost at night between foraging bouts. No males were recaptured during this study until just before sunrise. By contrast, females regularly returned to the roost during the night, undoubtedly to nurse their young. This nocturnal separation of the sexes is consistent with the behavior of other *M. lucifugus* colonies (Anthony et al. 1981). However, we cannot exclude the possibility that the disturbance of capture during this study may have caused the males to temporarily abandon the site each night until dawn.

Of the five species of bats that occur in Southeast Alaska, only *M. lucifugus* is common and widespread (West 1994; MacDonald and Cook 1996; Parker et al. 1997). The remaining four species, *M. keenii*, *M. californicus* (California Bat), *M. volans* (Long-legged Bat), and *Lasionycteris noctivagans* (Silver-haired Bat) are rare (Parker et al. 1997). The success of *M. lucifugus* is apparently due, in part, to its ability to exploit a wide variety of roost sites for maternity colonies including man-made structures such as houses, lodges buildings, and canneries (Barclay and Cash 1985; Parker et al. 1997). These structures provide stable thermal environments comparable to that of the hot spring roosts at White Sulfur Hot Springs and Gaandl Kin.

The low abundance of other bat species in the region may be related, in part, to a general lack of suitable natural roost sites warm enough for maternity colonies. While the temperate rainforests of Southeast Alaska contain abundant live trees, snags, and fallen logs suitable for bat roosts (Parker et al. 1997), few are likely to be thermally suitable for large maternity roosts. In Southeast Alaska, maximum summer temperatures typically range between 11°C and 16°C and rain occurs on an average of 20 days a month (National Oceanic and Atmospheric Administration 1992). Solar heating of potential roost sites in trees and snags is limited by rain and fog. In areas outside the north Pacific rainforests, natural roosts of *M. lucifugus*, *M. californicus, M. volans,* and *L. noctivagans* maternity colonies are most commonly found in sites that receive high levels of solar-heating. Nagorsen and Brigham (1993), for example, note that in the dry interior of British Columbia the largest bat maternity colonies occur in attics of buildings where daytime temperatures commonly reach 40°C. In a study of radio-tagged female Western Long-eared Bats (*M. evotis*), Vonhof and Barclay (1997) found the bats chose to roost in tree stumps in clearcut areas where increased exposure to sunlight and reflective heat provided roost environments significantly warmer than ambient temperatures. By contrast, the maritime environment of Southeast Alaska and coastal British

Columbia is considerably cooler and solar-heating is not likely to be sufficient to produce comparable thermal environments in many tree hollows or crevices. In a similar environment in the Cascade Mountain rainforests of Oregon, Thomas (1988) found that the sex ratio of *M. lucifugus* was skewed toward male bats, and females were nonreproductive. He concluded that extended periods of rain limited foraging opportunities for bats in this region and forced them into torpor. This physiological constraint presumably limited the reproductive capacity of the females in this region. We suggest that without the thermal benefits of adequately heated roost sites such as White Sulfur Hot Springs or man-made structures, the reproductive capacity and abundance of bats in Southeast Alaska is likely to be similarly limited.

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Literature Cited

Anthony, E. L., M. H. Stack, and **T. H. Kunz.** 1981. Night roosting and the nocturnal time budget of the little brown bat, *Myotis lucifugus*: effects of reproductive status, prey density, and environmental conditions. Oecologia 51: 151–156.

Barbour, R. W., and **W. H. Davis.** 1969. Bats of America. University of Kentucky Press. Lexington.

Barclay, R. M. R., and **G. P. Bell.** 1988. Marking and observational techniques. Pages 59-76 *in* Ecological and behavioral methods for the study of bats. *Edited by* T. H. Kunz. Smithsonian Institution Press. Washington.

Barclay, R. M. R., and **K. J. Cash.** 1985. A non-commensal maternity roost of the little brown bat (*Myotis lucifugus*). Journal of Mammalogy 66: 782–783.

Bell, G. P., G. A. Bartholomew, and **K. A. Nagy.** 1986. The role of energetics, water economy, foraging behavior, and geothermal refugia in the distribution of the bat *Macrotus californicus*. Journal of Comparative Physiology 156B: 441–450.

Burnett, C. D., and **P. V. August.** 1981. Time and energy budgets for dayroosting in a maternity colony of *Myotis lucifugus*. Journal of Mammalogy 62: 758–766.

Christy, R. E., and **S. D. West.** 1993. Biology of bats in Douglas-fir forests. General Technical Report PNW-GTR-308. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. 28 pages.

Davis, W. H., and **H. B. Hitchcock.** 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy 46: 296–313.

Fenton, M. B. 1970. Population studies of *Myotis lucifugus* (Chiroptera: Vespertilionidae) in Ontario. Life Science Contributions, Royal Ontario Museum 77: 1–34.

Fenton, M. B. 1983. Just bats. University of Toronto Press, Toronto, Ontario. 165 pages.

Fenton, M. B., and **R. M. Barclay.** 1980. *Myotis lucifugus*. Mammal Species 142: 1–8.

Firman, M., M. Getty, and **R. M. R. Barclay.** 1992. Status of Keen's long-eared *Myotis* in British Columbia. Wildlife Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia. Wildlife working report WR-59. 22 pages.

Hamilton, I. M., and **R. M. R. Barclay.** 1994. Patterns of daily torpor and day-roost selection by male and female big brown bats (*Eptesicus fuscus*). Canadian Journal of Zoology 72: 744–749.

Humphrey, S. R. 1975. Nursery roosts and community diversity of nearctic bats. Journal of Mammalogy 56: 321–347.

Kunz, T. H. 1982. Roosting ecology of bats. Pages 1-56 *in* Ecology of bats. New York. *Edited by* T. H. Kunz. Plenum Press.

Kurta, A. 1986. Insulation, thermoregulation, and metabolic rates of the little brown bat (*Myotis lucifugus*) under simulated roost conditions. Ph.D. dissertation, Boston University, Boston, Massachusetts.

Kurta, A., G. P. Bell, K. A. Nagy, and **T. H. Kunz.** 1989. Energetics of pregnancy and lactation in free ranging little brown bats (*Myotis lucifugus*). Physiological Zoology 62: 804–818.

MacDonald, S. O., and **J. A. Cook.** 1996. The land mammals of Southeast Alaska. The Canadian Field-Naturalist 110: 571–598.

McNab, B. K. 1982. Evolutionary alternatives in the physiological ecology of bats. Pages 151-200 *in* Ecology of bats. *Edited by* T. H. Kunz. Plenum Press, New York.

Motyka, R. J., and **M. A. Moorman.** 1983. Geothermal resources of Alaska. Alaska Division of Geological and Geophysical Surveys Professional Report. Map 1: 1,000,000. 1 sheet.

Nagorsen, D. W., and **R. M. Brigham.** 1993. Bats of British Columbia. Royal British Columbia Museum Handbook. University of British Columbia Press. Victoria, British Columbia. 164 pages.

National Oceanic and Atmospheric Administration (NOAA). 1992. Climatological Data: Alaska. National Climatic Data Center, Asheville, North Carolina.

Parker, D., B. E. Lawhead, and **J. A. Cook.** 1997. Distributional limits of bats in Alaska. Arctic 50: 256–265.

Racey, P. A. 1988. Reproductive assessment in bats. Pages 31-45 *in* Ecological and behavioral methods for the study of bats. *Edited by* T. H. Kunz. Smithsonian Institution Press. Washington.

Racey, P. A., and **S. M. Swift.** 1981. Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus pipistrellus*) from year to year. Journal of Reproduction and Fertility 61: 23–129.

Schowalter, D. B., J. R. Gunson, and **L. D. Harder.** 1979. Life history characteristics of little brown bats (*Myotis lucifugus*) in Alberta. Canadian Field-Naturalist 93: 243–251.

Serber, G. A. 1982. The estimation of animal abundance and related parameters. Macmillan Publishing Co., New York.

Studier, E. H., and **M. J. O'Farrell.** 1972. Biology of *Myotis thysanodes* and *M. lucifugus* (Chiroptera: Vespertilionidae) — Part I. Thermoregulation. Comparative Biochemistry and Physiology 41A: 567–595.

Thomas, D. W. 1988. The distribution of bats in different ages of Douglas-fir forests. Journal of Wildlife Management 52: 619-626.

Vonhof, M. J., and **R. M. R. Barclay.** 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74: 1797–1805.

Vonhof, M. J., and **R. M. R. Barclay.** 1997. Use of tree stumps as roosts by the western long-eared bat. Journal of Wildlife Management 61: 674–684.

Wang, L. C., and **M. W. Wolowyk.** 1988. Torpor in mammals and birds. Canadian Journal of Zoology 66: 133–137.

West, E. W. 1994. Second record of the long-legged bat (*Myotis volans*) in Alaska. Northwestern Naturalist 73: 56–57.

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Spatial and Temporal Patterns of Bird Use of Farmland in Southern Ontario

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To assess the factors behind possible global declines in some birds and to investigate the vulnerability of birds to agricultural practices, information is needed on bird use of farmland in much of Canada, including the Mixedwood Plains ecozone of southern Ontario. We examined the pattern of bird use of four crop types in three counties of southern Ontario (6 corn and 6 soybean fields, Essex County; 5–6 cornfields and 5–6 apple orchards, Norfolk County; 6 cornfields and 6 vineyards, Niagara County) during July–September 1987 and May–September 1988. Of the 138 species recorded in all three counties (1987–1988 combined), 25 were seen on 50% of visits and 16 at frequencies between 25 and 50% of visits in at least one crop during any one month. Cornfields had more species than orchards in Norfolk and vineyards in Niagara, whereas in Essex, soybeans had more species than corn. The species most frequently observed in cornfields were Song Sparrow (*Melospiza melodia*), European Starling (*Sturnus vulgaris*), Red-winged Blackbird (*Agelaius phoeniceus*) and Common Grackle (*Quiscalus quiscula*). In soybean fields, the most frequently recorded species were Horned Lark (*Eremophila alpestris*), Song Sparrow and Common Grackle, whereas in orchards, Chipping Sparrow (*Spizella passerina*) was the most frequently recorded species. In vineyards, American Robin (*Turdus migratorius*), Savannah Sparrow (*Passerculus sandwichensis*) and American Goldfinch (*Carduelis tristis*) were the species most commonly observed. Most species occurred uncommonly (recorded on < 25% of visits) in all months, and very few species were recurrent (75% of visits). Omnivorous and insectivorous species were most abundant in all crop types, and more ground feeders were observed than species foraging in the canopy, aerially or in aquatic habitats. Thirty-five species were only recorded during the migration period of August/September.

Key Words: Birds, croplands, breeding season, migration period, southern Ontario.

Increasing concern is being expressed over declines in farmland and grassland bird populations, both in North America (Askins 1993; Warner 1994; Knopf 1994, 1995) and western Europe (Marchant et al. 1990; Robertson and Berg 1992; Fuller et al. 1995; Greenwood 1995). There are two primary reasons for this concern. First, farmland landscapes occupy extensive areas, are extremely important for many bird species, and have been subject to rapid and large scale changes in recent years (see O'Connor and Shrubb 1986; Rodenhouse et al. 1995; McLaughlin and Mineau 1995; Mineau and McLaughlin 1996 for reviews). Second, agricultural practices have resulted in decreased regional biodiversity in farmland (Freemark 1995; Mineau and McLaughlin 1996).

According to the latest analysis of the Breeding Bird Survey (BBS) in Canada, significant long-term (1966-1994) declines have occurred in many grassland and farmland bird species, including Savannah Sparrow, Bobolink and Eastern Meadowlark (scientific names are in Appendix) in the Mixedwood Plains ecozone (parts of southern Ontario and southern Québec; Downes and Collins 1996; see also Jobin et al. 1996). Although the causes of these declines have not been firmly established for many species, and are likely to differ according to life history traits, an important first step is to determine which components of farmland ecosystems are used by birds

There are relatively few data available on bird species abundance in different crop types. Avian use of farmland has been documented recently in Britain (Fuller 1984; O'Connor and Shrubb 1986; Tucker 1992; Wilson et al. 1996) and for Illinois, Iowa and Indiana in the United States, both in relation to use of crops by different bird species (e.g., Graber and Graber 1963; Castrale 1985; Basore et al. 1986; Best et al. 1990), and for non-crop habitats such as fencerows (Best 1983), roadsides (Camp and Best 1994) and grassed waterways (Bryan and Best 1991). However, there is a paucity of information for Canada. In their extensive review of bird use of farmland in the Great Lakes-St. Lawrence region, Freemark et al. (1991) suggested that small fruit crops were important for birds. However, most of the studies in small fruit crops reviewed were conducted as a result of bird damage and mitigative control measures, clearly introducing biases into the perceived importance of these crops, relative to others, for birds (Freemark et al. 1991, and references therein). Therefore, we felt that a more objective assessment of bird use of crops was needed in Canada, both in relation to the use of birds as indicators of environmental change (Furness and Greenwood 1993), and for guiding management decisions in agriculture that may affect avian biodiversity (McLaughlin and Mineau 1995; Mineau and McLaughlin 1996). As such, this represents the first summary of bird use of cropland in southern Ontario (but see Jobin et al. 1998, for southern Quebec); an early study by Speirs and Orenstein (1967) focused on grassland.

In this paper, we describe spatial and temporal patterns of bird use of farmlands in southern Ontario over a two-year period. One unique aspect of our study is that we document intensively bird use of cropland over the course of both the breeding and part of the migration season; previous studies in North America (e.g., Best et al. 1990) combined data over the breeding season. Specifically, our goal in this paper is (1) to document the species using four types of crops and their immediate edges in southern Ontario during the breeding and migrating seasons, and (2) to ascertain the between- and within- year pattern of crop use by birds.

Methods

Study areas and crop types

We selected four crop types for assessment of avian use in three counties in southern Ontario (Figure 1). Corn (for silage) was chosen because it was common to all three counties, had a high acreage (total county acreage 24 019 ha in Essex, 35 759 ha in Norfolk and 15 070 ha in Niagara; Statistics Canada 1987) and it had regular pesticide applications (see Boutin et al. 1996; Boutin et al. *in press*). A second crop with a large acreage and known to have frequent or intensive management, particularly pesticide use, was selected in each county. For Essex County the crop was soybeans (total acreage 60 781 ha), for Haldimand-Norfolk County (hereafter Norfolk), apple orchards (1378 ha) and for Niagara County, grape vineyards (7332 ha). The total acreage for these four crops in southern Ontario was 452 041 ha (corn), 320 293 ha for soybeans, 6110 ha for apple orchards and 8 154 ha for grapes (fruit-bearing plants only; Statistics Canada 1987).

We selected six fields of each crop type per county that were representative of field sizes in the region, and that were square or rectangular in shape; both field size and shape can affect bird communities because of differing edge to interior ratios (Best et al. 1990). Field sizes ranged from 11.4 to 24.5 ha, with one field being 40.5 ha (the average field size was 21 ha; based on field sizes from Essex County). Because of crop rotation, we had to select different fields in 1987 and 1988 for corn and soybean crops (except in two cases for corn where the same fields were used in both years). However, in all except one case the same apple orchards were surveyed in both years; vineyards were surveyed only in 1987. The study areas in each county were sufficiently far apart (> 10 km) to avoid pseudoreplication of bird census data.

FIGURE 1. Location of study counties used to assess bird use of farmland in southern Ontario: Essex, Norfolk and Niagara counties.

Bird survey techniques

A combination of point counts and transects was used to survey birds. Point counts allow observation of birds from a stationary point and are being increasingly used to survey cropland birds (e.g., Cyr et al. 1995). By also counting new birds on transects between points, the chance is minimized of missing individuals of secretive or wary species, or from changes in detectability as crops grew and song activity diminished later in the season. Within each field ten points were located, eight of which were along the perimeter of the field, two on each side, and two in the centre. Stations were located 200 m apart. Although this is closer than the recommended distance between points in open habitats (500 m) to ensure statistical independence between points and transects (Ralph et al. 1995), observers attempted not to count the same individuals more than once. Count duration was three minutes, which was a compromise between station density and count duration.

Birds were recorded as using field interiors or edge habitats, the latter being defined as a 10-m wide area immediately adjacent to field crops. Birds that flew high over fields were not included because their association with crops or other habitats could not be established with certainty. However, individuals that flew low over fields, such as swallows and martins, were considered to be using the interior of fields, because they were feeding on invertebrates flying over the field substrate.

We tried to ensure that the same observers counted birds within counties and among years but this was not always possible. The same observers counted birds in both years in Essex corn and soybeans and in Norfolk apple orchards but different observers surveyed Norfolk cornfields in each year. Crop fields in Niagara County could be surveyed only in 1987.

Counts were conducted from July to mid-September in 1987 and from May to mid-September in 1988. Financial and time constraints prevented us from obtaining data for May and June, 1987. In 1987, counts were conducted on three visits daily (morning: 04:45-09:45, mid-day 09:46-14:00 and evening 14:01-22:00) for five days each week. To minimize differences in counts attributable to time of day, a three-day rotational schedule was followed for the six fields per crop in each county. Because evening visits resulted in the addition of only 5-9 new species and generally only a few more individuals, and because of time constraints, we discontinued them in the 1988 surveys (see Boutin et al. 1996 for details). However, we continued to alternate morning and mid-day visits among fields to minimize differences in bird abundance attributable to time of day. Counts were made only in good weather conditions. Mean duration of visits ranged from 61-90 min. for cornfields, 72-79 min. for soybeans, 63-87 min. for apple orchards and 61-71 min. for grapes (for details see Boutin et al. 1996).

Analyses of data

Because of variability in the number and timing of bird surveys (Boutin et al. 1996), and the use of different fields between years due to crop rotation, we analyzed data from 1987 and 1988 separately. We summarised the data monthly using the % frequency of occurrence and mean abundance for all bird species in fields of each crop type and for each county. We pooled data from August and September for some summaries because counts were made only during the first two weeks in September. We assigned bird species to four frequency classes on the basis of their occurrence in the crop fields as follows; recurrent 75% and more; regular < 75% to 50%; occasional < 50% to 25%; and uncommon < 25% in a similar fashion to Best et al. (1990). We also assigned species to foraging guilds based on DeGraaf et al. (1985) and Erhlich et al. (1988).

We compared the similarity of bird communities among counties and crop types using the Sørenson coefficient of community (Jongman et al. 1995):

$$CC = 2a / (b + c + 2a)$$

where a = the number of species common to both crops/counties and b and c are the numbers of species recorded exclusively in one crop/county or the other. We recognise that our unequal sampling design could invalidate this procedure. However, given that many visits were made to fields and species accumulation curves indicated that 80% of species were recorded after 9-27 visits in all months except August-September, we believe that this coarse similarity index using all months combined was justified. All data handling was performed using SAS PC + software (SAS Institute 1989).

Results

Species richness

Altogether, 138 species were counted in the four crops over the two-year period and of these, 119 were recorded in 1987 and 118 in 1988 (see Appendix for details). Thus, despite the fact that coverage was for only two months in 1987, overall species richness was almost identical to that in 1988, perhaps because vineyards were only surveyed in 1987. To corroborate this, although species richness varied by crop and month, Figure 2 shows that the total and average number of species was usually higher in 1988 in all crops surveyed both years. The mean bird abundance was also lower in most months of 1987 except in September in Norfolk County where large flocks of Tree and Bank swallows, European Starlings, Chipping Sparrows and especially Red-winged Blackbirds (Appendix) altered the pattern (Figure 3). As a percentage of all species in each crop, the proportion that were recurrent (seen on 75% of visits) was very low (7-15% of species in corn, 9-36% in soybean, 12-20% in apple orchards and 5-20% in vineyards; Figure 4). Most species were uncommon (< 25% of visits) and generally their proportion increased in the August/September migration period for all crop types (Figure 4).

Overall, corn held most species (125), followed by apple orchards (91), soybeans (89) and vineyards (61). That these differences were real and not just due to unequal sampling effort was demonstrated by within-county comparisons. For example, in Norfolk, more species were counted in corn (80 in 1987, 92 in 1988) than orchards (66 and 80, respectively). Similarly, in Niagara, there were more species in corn (85) than vineyards (61). By contrast, in Essex, soybeans held more species (62 species in 1987, 82 in 1988) than corn (58 and 70, respectively).

We next compared the species composition of the two crops surveyed in each county within years to see how much overlap there was in their communities. In Essex, there tended to be fewer species unique to cornfields compared to the number found only in soybean fields. For example, in 1987, 48 species were common to corn and soybean, 10 were found only in corn and 12 only in soybeans. Respective values for 1988 were 62 species (corn and soybean), 8 species (corn alone) and 20 species (soybeans alone). The reverse was true for Norfolk and Niagara counties. In Norfolk (1987), 51 species were common to corn and orchards, whereas 28 were seen only in corn and 17 only in orchards. In 1988, respective values were 69 species (corn and

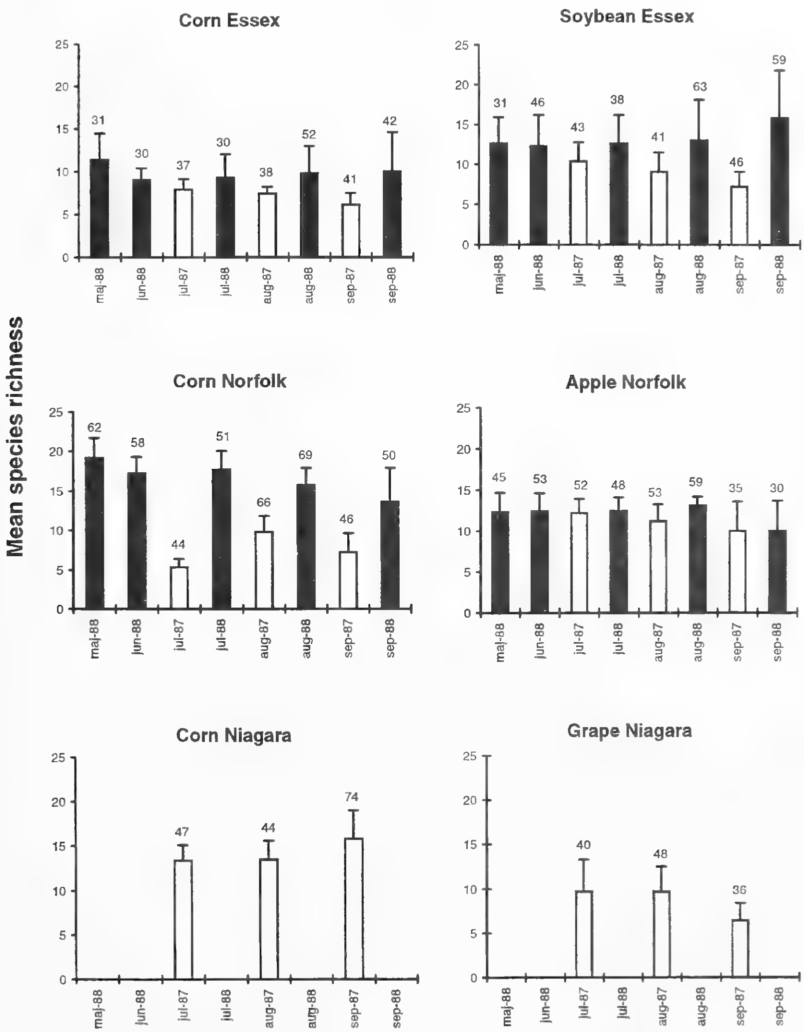

FIGURE 2. Mean bird species richness (± SE) per field per visit in different crop types in different months. Total number of species is shown above the bar. Dark bars = 1988 survey, open bars = 1987. See Appendix for species.

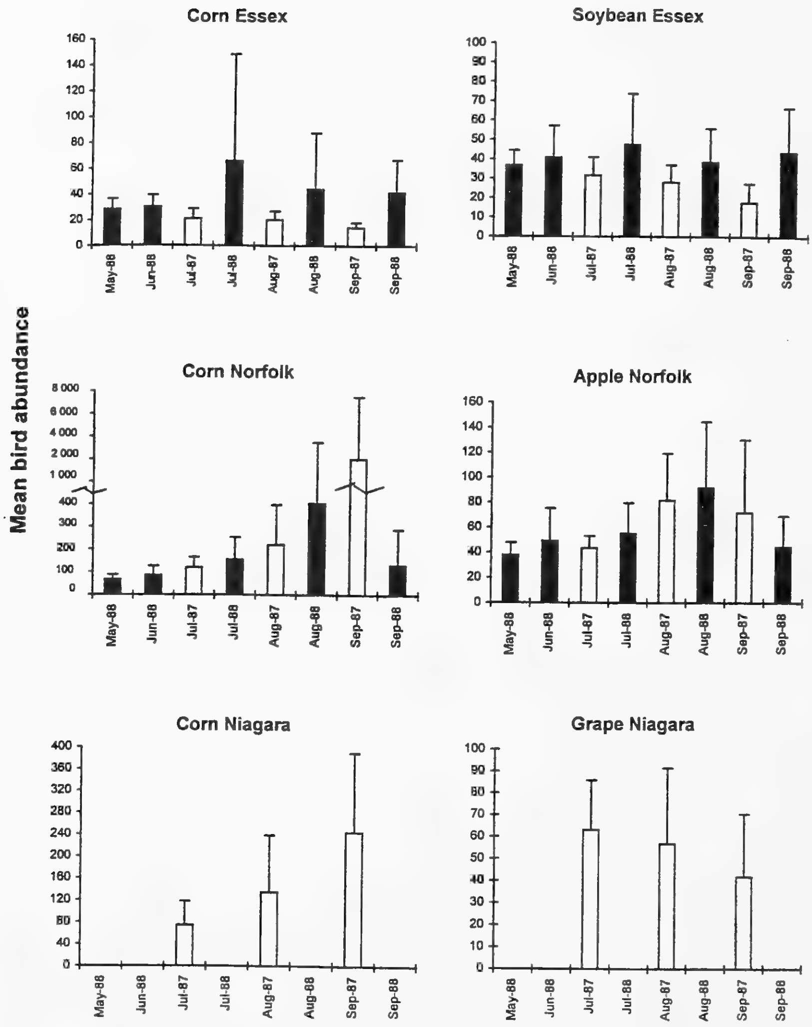

FIGURE 3. Mean bird abundance (± SE) per field per visit in different crop types in different months. Dark bars = 1988 survey, open bars = 1987.

orchards), 19 species (corn alone) and 16 species (orchards alone). Finally, in Niagara, 53 species were found in both corn and grapes; 32 species were only in corn and eight species only in vineyards (see Appendix).

Similarity indices suggested that a geographic difference existed between counties in their bird species composition. Essex corn was always more similar to Essex soybean than to Norfolk and Niagara corn during both the breeding and migration periods, and overall (Table 1). Conversely, no general pattern existed in Norfolk and Niagara. However, Norfolk apple and corn differed considerably in 1987 in the migration period.

Diet and food substrate guilds by crop type and month

The general trend in all crop types was for omnivorous species to be most abundant, followed by insectivores (Figure 5). Exclusively granivorous species were relatively rare, as were carnivorous species (raptors). Cornfields were combined for all three counties to provide an overall picture. There was a tendency for the number of species in the omnivorous and insectivorous classes to increase in all crop types in August/September. This was particularly noticeable in corn where numbers of insectivorous species greatly outnumbered omnivorous ones in August/September (Figure 5); this was attributable

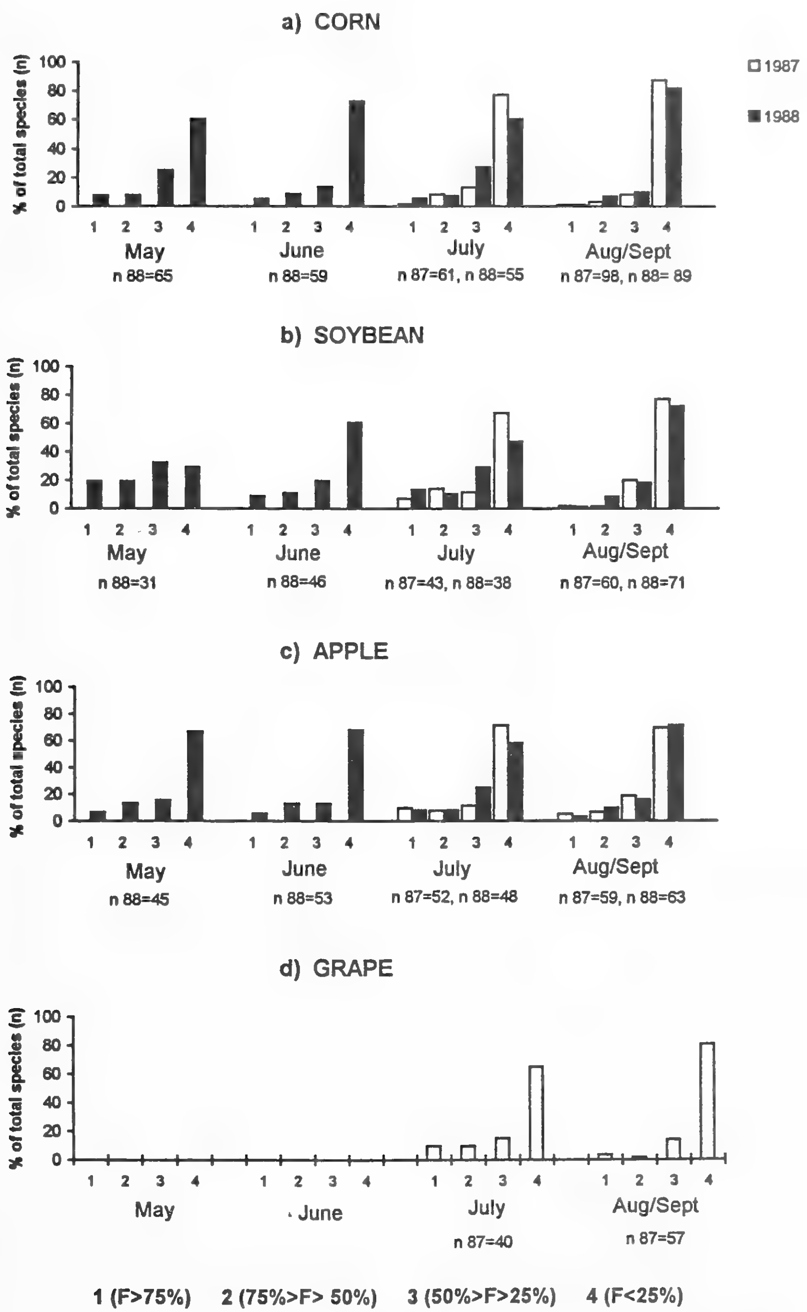

FIGURE 4. Percentage of total number of species recorded in different months by frequency of occurrence in a) corn fields, b) soybean fields, c) apple orchards and d) grape vineyards. n = total number of species in 87 and 88.

to the large numbers of migrants using corn at this time.

Ground-foraging species were most abundant in all crop types in every month (Figure 6). In corn ground foragers increased in August/September, as did lower canopy and upper canopy foragers. To a lesser extent this was also true in other crop types, but not for apple orchards (see Figure 6).

TABLE 1. Sørenson coefficients of similarity among counties, crop types and years. The breeding period includes months of May, June and July, the migration period includes August and September, and total includes all months. Breeding data for 1987 only include July. Only coefficients between same crops and same counties were calculated.

			Sørenson coefficients	
			1987	1988
a) Breeding period				
Essex corn	with	Essex soybean	0.85	0.82
	with	Norfolk corn	0.74	0.66
	with	Niagara corn	0.67	not available
Norfolk corn	with	Norfolk apple	0.78	0.77
	with	Niagara corn	0.76	not available
Niagara corn	with	Niagara grape	0.73	not available
b) Migration period				
Essex corn	with	Essex soybean	0.73	0.82
	with	Norfolk corn	0.65	0.70
	with	Niagara corn	0.65	not available
Norfolk corn	with	Norfolk apple	0.62	0.72
	with	Niagara corn	0.77	not available
Niagara corn	with	Niagara grape	0.72	not available
c) Total period				
Essex corn	with	Essex soybean	0.81	0.81
	with	Norfolk corn	0.70	0.76
	with	Niagara corn	0.67	not available
Norfolk corn	with	Norfolk apple	0.69	0.80
	with	Niagara corn	0.77	not available
Niagara corn	with	Niagara grape	0.75	not available

Frequency of species occurrence by crop type, county and month

In cornfields, Song Sparrow was the most frequently recorded species (75% of visits in each month); it was recurrent in all months, except for August-September in Essex when it was regular (see Appendix). The maximum abundance for the species ranged between 9 and 27. European Starling, Red-winged Blackbird and Common Grackle were also recurrent or regular and occurred in large numbers (see Appendix). Other species that occurred frequently in most months but generally in lower numbers were Mourning Dove, Horned Lark, Barn Swallow, American Robin, Savannah Sparrow, Brown-headed Cowbird, American Goldfinch and House Sparrow. In addition, Yellow Warbler was recurrent (May-July 1988) or occasional (August-September) in Norfolk.

In soybeans the most frequently detected species in all months was the Song Sparrow (recurrent in all months except August-September 1988, when it was regular). Other sparrows were well represented in soybeans, e.g. Chipping Sparrow (recurrent in July 1988, regular in May and June 1988 and occasional other times), Vesper Sparrow (recurrent in May 1988, regular in June and July and occasional in August-September both years) and House Sparrow (recurrent in June 1988 and July 1987, regular in other months of 1988 and occasional in August-September 1987). Maximum abundance for these four species ranged from 2 to 53. Six other species were recurrent at least in one month: Killdeer, Purple Martin, Horned Lark, Barn Swallow, American Robin and Common Grackle (see Appendix).

In orchards the most frequently recorded species was the Chipping Sparrow, which was recurrent in all months (75% of visits). The Savannah Sparrow was also recurrent from May-July 1988, as was Song Sparrow in May-June (Appendix). Both Chipping and Savannah sparrows were observed in flocks in August-September, with a maximum abundance of 217 and 82, respectively. Other species frequently observed in orchards included Mourning Dove (recurrent July-September in both years), American Crow (regular in all months), Barn Swallow (recurrent in July 1987, regular all other months) and American Goldfinch (recurrent or regular in July-September of both years or occasional in May-June 1988). Additional common species found less in other crop types were Eastern Bluebird, Eastern Towee, Cedar Waxing and Field Sparrow which were occasional or uncommon (see Appendix).

Finally, in vineyards, the most frequent species were American Robin and American Goldfinch (both recurrent in July-September); Chipping Sparrow was also recurrent here in July but regular in August-September and Song Sparrow was regular in July but occasional in August-September.

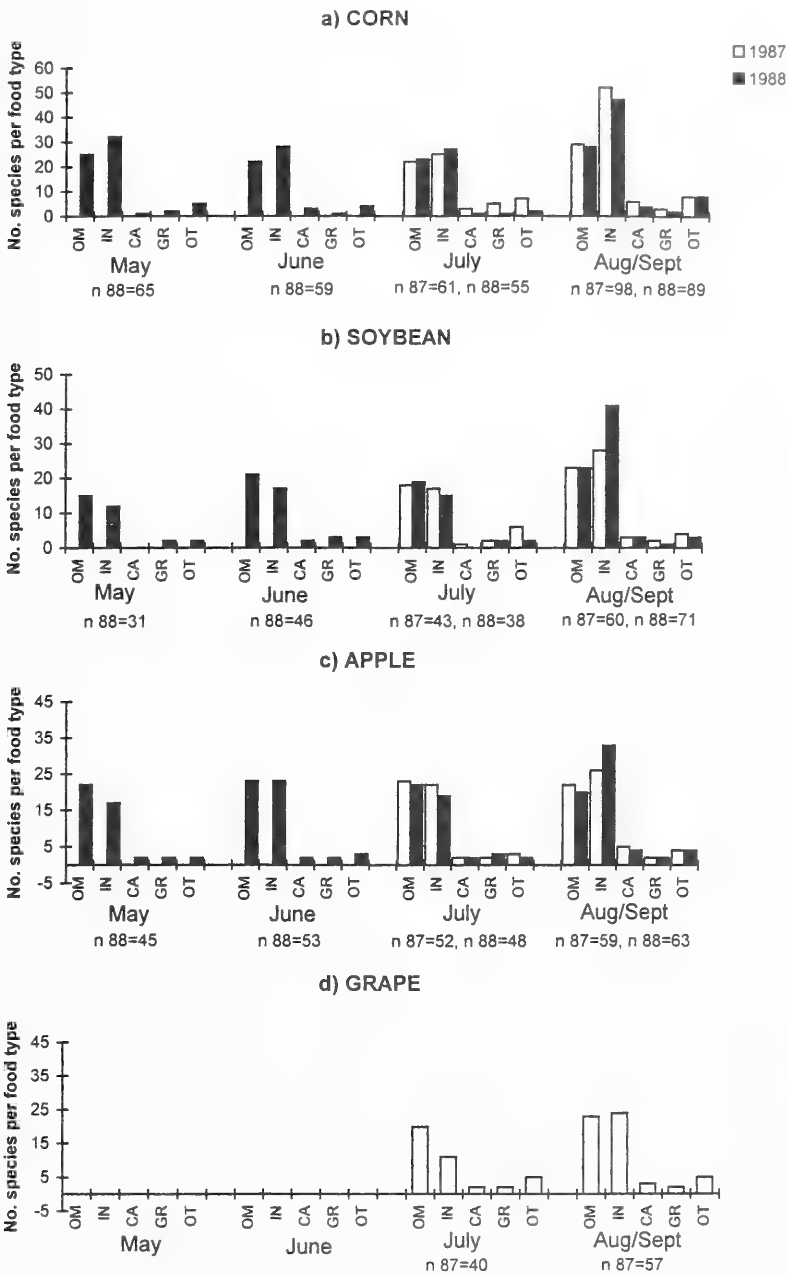

FIGURE 5. Total number of species classified by diet in a) corn fields, b) soybean fields, c) apple orchards and d) grape vineyards. Codes are: OM = omnivorous, IN = insectivorous, CA = carnivorous, GR = granivorous, OT = others.

Maximum abundance was high for the American Robin (33 and 65) and the Chipping Sparrow (13 and 26). Regular or occasional species in all months counted included Killdeer, Mourning Dove, Northern Flicker, European Starling, Savannah Sparrow, House Finch, and House Sparrow (Appendix).

Several species used the interior of cropfields at least once during the survey (Appendix). Species flying over while foraging were considered as foraging

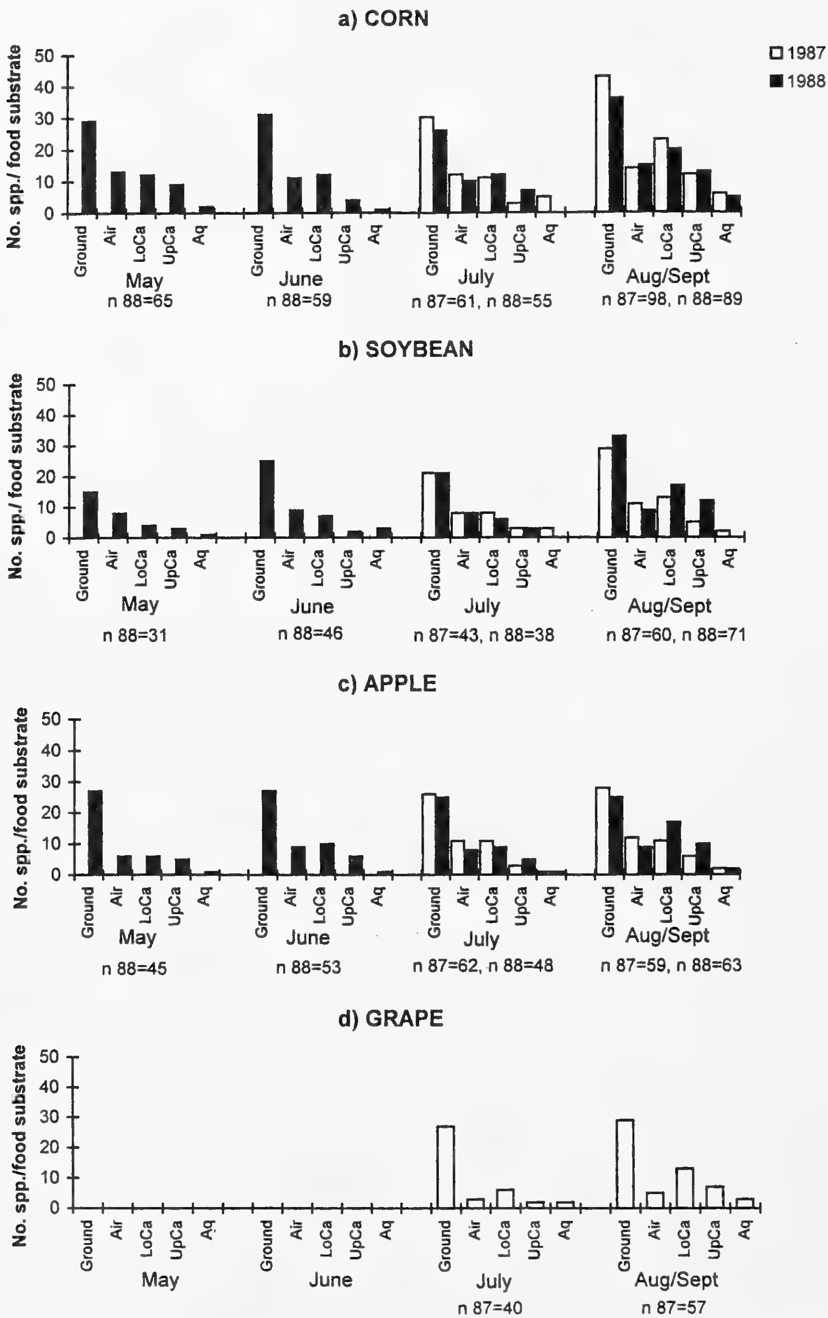

FIGURE 6. Total number of species classified by foraging substrate in a) corn fields, b) soybean fields, c) apple orchards and d) grape vineyards. Codes are: Ground, Air, LoCa = low canopy, UpCa = upper canopy, Aq = aquatic.

in the field interior, e.g. swallows, Purple Martin, and Chimney Swift. Nevertheless most species occurred more often in the edge habitats than in the interior, especially warblers.

Transient or migratory species

Altogether, 35 species were recorded only in August or September (both years combined), 41 species being recorded only in August or September in 1987 and 29 in 1988. Overall, for both years combined, 26 species were recorded as uncommon (< 25% and < 10 individuals maximum count) during the autumn migration period (Appendix).

The number of species using different crops during August-September alone was similar for Norfolk County with 35 and 17 species using cornfields, and 31 and 17 species used apple orchards in 1987 and 1988, respectively. However in Essex, more species tended to use soybean fields during these months than used the other crop, 22 and 19 species used cornfields and 28 and 29 species used soybean fields on autumn migration, in 1987 and 1988, respectively. In Niagara, the reverse occurred, 38 species used cornfields and 21 used vineyards in 1987 (see Appendix).

Nine species were recorded during both the spring and autumn migration period in at least one county (American Black Duck, Osprey, Cooper's Hawk, Merlin, Black-bellied Plover, Chimney Swift, Yellow-rumped Warbler, Black-throated Green Warbler, Bay-breasted Warbler). Only three species were recorded only in May during the spring migration period (Blue-gray Gnatcatcher, White-crowned Sparrow and Orchard Oriole; see Appendix).

Discussion

Our results demonstrate that there is great variation in bird species composition and abundance among crops, among counties and at different times of the year. Generally, except for Essex County, cornfields held more bird species than other crops, as suggested by others (Freemark et al. 1991; Best et al. 1995). Although we did not consider non-crop habitats and field size in this comparison, this finding supports the hypothesis that more bird species are positively associated with grain crops because these provide a potential source of food (Rodenhouse et al. 1995) either during harvest, or in the late fall/early spring. Compared to previous studies, we found more species associated with corn (total 125; 81 in Essex, 106 in Norfolk, 85 in Niagara) and soybean fields (89); in Illinois, Graber and Graber (1963) recorded 39 species in corn and 27 in soybeans, whereas Best et al. (1990) found 53 and 30 species (63 in total), in Illinois and Iowa cornfields, respectively. Freemark et al. (1991) documented 68 species in corn and 44 in soybean, respectively, in the Mixedwood Plains ecozone. Moreover, we found more species in apple orchards (91) and grapes (61) than reported previously for this ecozone (7 and 29, respectively; Freemark et al. 1991). Undoubtedly, these differences were largely due to the more extensive coverage of migration and breeding season in our study, which had not been previously documented. However, direct comparisons with these other studies are not strictly valid for several reasons. First, Freemark et al. (1991) combined species lists (most of them incomplete) from studies in the Great Lakes Region of the United States and Canada. Second, different census techniques and sample effort were used and finally, geographical variation in bird distribution and abundance patterns was not considered.

Apart from documenting breeding bird use of crops, our study also highlighted the importance of farm fields as stopover habitat for migratory birds. Our study fields were situated close to three major migration corridors used by migrants on their way southwards during the fall (Figure 1); the Niagara Peninsula (between Lakes Ontario and Erie in Niagara County), Long Point (Norfolk) and Point Pelee (Essex). Of the 35 species recorded exclusively during August and September for both years pooled, 14 have not bred recently in any of these three counties (Cadman et al. 1987); there are historical records for a further four species (Peck and James 1987). Some of these were typically northern boreal forest breeding species such as Merlin, Gray-cheeked Thrush, Swainson's Thrush, Philadelphia Vireo, Palm Warbler, Blackpoll Warbler, Lincoln's Sparrow and Rusty Blackbird. Others were shorebird species that breed in the high arctic, such as Black-bellied Plover and Pectoral Sandpiper; use of agricultural fields by shorebirds on migration has been documented recently in Virginia (Rottenborn 1996). Species that breed largely on, or north of the Canadian Shield included Ruby-crowned Kinglet, Cape May Warbler and Black-throated Blue Warbler. Only White-crowned Sparrow was counted exclusively in May, and this is a species that breeds in the subarctic (Hudson Bay lowlands in Ontario; Cadman et al. 1987). Twenty species exclusively found during the fall migration period were insectivorous species (many warblers). Eighteen species were ground foragers (thrushes, sparrows, some warblers, etc.).

Many factors affect the use of crops by birds, such as the intrinsic characteristics of crop vegetation (which for most crops varies seasonally as plants begin to grow), how these crops are managed (i.e., tillage operations, the amount of crop residue and so on), and perhaps most importantly, the structural characteristics of, and area covered by, non-crop habitats (e.g., field margins, fencerows and hedgerows; Arnold 1983; Best et al. 1983; Best et al. 1995). Corn, for example, provides greater cover in late summer and early autumn when it is 2 m or more tall and has a closed canopy than say, vineyards, so this may partly account for the higher bird species richness of corn — and the larger number of migratory species using it. However, in Essex, soybeans had higher species richness than corn. It is likely that differences in non-crop habitats adjacent to fields contributed to the higher species richness in soybeans than corn (see below).

In the present study the close association of bird species with the type of habitats adjacent to fields inventoried was not investigated (albeit some *a posteriori* data were collected [Boutin et al. 1996]) nor was information collected on the size and proximity of habitat patches at the regional level, which has been established in the literature as important to birds in agricultural areas (Morgan and Gates 1982; Yahner 1988). Although the region was quite homogeneous, a few species may have been associated with particular attributes of the landscape, e.g. small marshes, small woodlots or permanent grassy stretches. Consistently more species and individuals were counted in Norfolk (total 106) than in Essex (total 81), both areas having been censused in 1987 and 1988. Less than 4% of the region is composed of "natural" habitats in Essex County whereas 25% of Norfolk County, particularly in the south, is still forested, although somewhat fragmented (Friesen 1994). Essex County appeared to be the most intensively cropped county and had the least amount of native habitat adjacent to crop fields. Norfolk County appeared to have the most diverse mix of crop and non-crop habitats adjacent to crop fields. Niagara was intermediate between the other two.

Differences between counties in bird diversity may also be ascribed to regional variation in cropland. Norfolk County produces nearly one-quarter of all apples in southern Ontario (Statistics Canada 1987). The geographical proximity of Niagara County, which produced up to 90% of southern Ontario grapes in 1987, may have influenced bird distribution.

In the current investigation, several bird species were observed using landscapes where agriculture prevails; however, the commonest are generalists that are adaptable and can be accommodated in disturbed human-made habitats. Forest-dwelling species have retreated from large parts of southern Ontario following the disappearance of the Carolinian forest (Peck and James 1983, 1987). Grassland species are decreasing dramatically with the transformation of agriculture from a diversified mixture of pasture land, perennial and annual crops (Askins 1993) to more homogeneous landscapes. The intensification of agriculture, exemplified by monocultures planted in increasingly larger fields, the destruction or simplification of marginal habitats and the extensive use of agro-chemicals for pest and weed control, is creating landscapes that have been termed ecological deserts (Ratti and Scott 1991). Because landscapes in southern Ontario continue to be modified due to new agricultural practices and urbanization, more studies are needed to better understand avian population dynamics, during the breeding and the migration periods, in an attempt to reconcile these changes with the preservation of avian biodiversity.

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Literature Cited

Arnold, G. W. 1983. The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. Journal of Applied Ecology 20: 731–750.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11: 1–34.

Basore, N. S., L. B. Best, and **J. B. Wooley, Jr.** 1986. Bird nesting in Iowa no-tillage and tilled cropland. Journal of Wildlife Management 50: 19–28.

Best, L. B. 1983. Bird use of fencerows: implications of contemporary fencerow management practices. Wildlife Society Bulletin 11: 343–347.

Best, L. B, R. C. Whitmore, and **G. M. Booth.** 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. American Midland Naturalist 123: 84–99.

Best, L. B., K. E. Freemark, J. J. Dinsmore, and **M. Camp.** 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. American Midland Naturalist 134: 1–29.

Boutin, C., K. E. Freemark, D. V. Weseloh, G. M. Donaldson, M. Csizy, P. A. Martin, A. Wormington, J. McCracken, and **D. Shepherd.** 1996. Bird use of crops in southern Ontario: implications for assessment of pesticide use. Canadian Wildlife Service Headquarters, Technical Report Series Number 264, Environment Canada, Hull, Québec, Canada.

Boutin, C., K. E. Freemark, and **D. A. Kirk.** *in press.* Farmland birds in southern Ontario: field use, activity patterns and vulnerability to farmland management. Agriculture, Ecosystems and Environment.

Bryan, G. G., and **L. B. Best.** 1991. Bird abundance and species richness in grassed waterways in Iowa rowcrop fields. American Midland Naturalist 126: 90–102.

Cadman, M. D., P. F. J. Eagles, and **F. M. Helleiner.** 1987. Atlas of the breeding birds of Ontario. Federation of Ontario Naturalists and Long Point Bird Observatory. University of Waterloo Press, Waterloo, Ontario.

Camp, M., and **L. B. Best.** 1994. Nest density and nesting success of birds in roadsides adjacent to rowcrop fields. American Midland Naturalist 131: 347–358.

Castrale, J. S. 1985. Responses of wildlife to various tillage conditions. Transactions of the North American Wildlife and Natural Resources Conference 50: 142–156.

Cyr, A., D. Lepage, and **K. Freemark.** 1995. Evaluating point-count efficiency relative to territory mapping in cropland birds. Pages 63–67 *in* Monitoring bird populations by point counts. *Edited by* C. J. Ralph, J. R. Sauer and S. Droege. USDA Forest Service General Technical Report PSW-GTR-149, Pacific Southwest Research Station, Albany, California.

DeGraaf, R. M., N. G. Tilghman, and **S. H. Anderson.** 1985. Foraging guilds of North American birds. Environmental Management 9: 493–536.

Downes, C., and **B. T. Collins.** 1996. The Canadian Breeding Bird Survey, 1966–94. Canadian Wildlife Service Progress Note Number 210. 36 pages.

Erhlich, P. R., D. F. Dobkin, and **D. Wheye.** 1988. The birders handbook. A field guide to the natural history of North American birds. Simon and Schuster Inc. New York.

Freemark, K. E. 1995. Assessing effects of agriculture on terrestrial wildlife: developing a hierarchical approach for the US EPA. Landscape and Urban Planning 31: 99–115.

Freemark, K. E., H. Dewar, and **J. Saltman.** 1991. A literature review of bird use of farmland habitats in the Great Lakes — St. Lawrence region, Canadian Wildlife Service Technical Report Series Number 114, Environment Canada, Ottawa. 28 pages + appendices.

Friesen, L. 1994. A literature review on wildlife habitats in agricultural landscapes. Canada-Ontario Agriculture Green Plan, Report Number RES/MAN-009/94. 67 pages.

Fuller, R. J. 1984. The distribution of breeding songbirds on cereal farmland at Manydown Farm, Hampshire, in 1984. Report to the Game Conservancy, British Trust for Ornithology, Tring, U.K.

Fuller, R. J., R. D. Gregory, D. W. Gibbons, J. H. Marchant, J. D. Wilson, S. R. Baillie, and **N. Carter.** 1995. Population declines and range contractions among lowland farmland birds in Britain. Conservation Biology 9: 1425–1441.

Furness, R. W., and **J. J. D. Greenwood.** *Editors.* 1993. Birds as monitors of environmental change. Chapman and Hall, London.

Graber, R. R., and **J. W. Graber.** 1963. A comparative study of bird populations in Illinois, 1906–1909 and 1956-1958. Illinois Natural History Survey Bulletin 28: 383–528.

Greenwood, J. J. D. 1995. A second silent spring? Trends in Ecology and Evolution 10: 264–266.

Jobin, B., J. L. DesGranges, and **C. Boutin.** 1996. Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. Agriculture, Ecosystems and Environment 57: 103–116.

Jobin, B., J. L. DesGranges, and **C. Boutin.** 1998. Crop use by farmland birds in southern Québec. Canadian Field-Naturalist 112: 611–618.

Jongman, R. H. G., C. J. F. ter Braak, and **O. F. R. van Tongeren.** 1995. Data analysis in community and landscape ecology. Cambridge University Press. Cambridge, England.

Knopf, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15: 247–257.

Knopf, F. L. 1995. Declining grassland birds. Pages 296–298 *in* Our living resources. A report to the Nation on the distribution, abundance and health of U. S. plants, animals, and ecosystems. *Edited by* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran and M. J. Mac. U. S. Department of Interior, National Biological Service, Washington, D. C.

Marchant, J. H., R. Hudson, S. P. Carter, and **P. Whittington.** 1990. Population trends in British breeding birds. British Trust for Ornithology (BTO), Tring, England.

McLaughlin A., and **P. Mineau.** 1995. The impact of agricultural practices on biodiversity. Agriculture Ecosystems and Environment 55: 201–212.

Mineau, P., and **A. McLaughlin.** 1996. Conservation of biodiversity within Canadian agricultural landscapes: Integrating habitat for wildlife. Journal of Agriculture and Environmental Ethics 9: 93–113.

Morgan, K., and **J. Gates.** 1982. Bird population patterns in forest edge and strip vegetation at Remington Farms, Maryland. Journal of Wildlife Management 46: 933–944.

O'Connor, R. J., and **M. Shrubb.** 1986. Farming and birds. Cambridge University Press, Cambridge, England. 290 pages.

Peck, G. K., and **R. D. James.** 1983. Breeding Birds of Ontario. Nidiology and distribution. Volume 1: Nonpasserines. The Royal Ontario Museum, Toronto. Ontario. 321 pages.

Peck, G. K., and **R. D. James.** 1987. Breeding Birds of Ontario. Nidology and distribution. Volume 2: Passerines. Royal Ontario Museum, Toronto. Ontario. 387 pages.

Ralph, C. J., S. Droege, and **J. R. Sauer.** 1995. Managing and monitoring birds using point counts: standards and applications. Pages 161–168 *in* Monitoring bird populations by point counts. *Edited by* C. J. Ralph, J. R. Sauer and S. Droege. USDA Forest Service General Technical Report PSW-GTR-149, Pacific Southwest Research Station, Albany, California.

Ratti, J. T., and **J. M. Scott.** 1991. Agricultural impacts on wildlife: problem review and restoration needs. Environmental Professional 13: 263–274.

Robertson, J. G., and **C. Berg.** 1992. Status and population changes of farmland birds in southern Sweden. Ornis Svecica 2: 119–130.

Rodenhouse, N. L., L. B. Best, R. J. O'Connor, and **E. K. Bollinger.** 1995. Effects of agricultural practices and farmland structures. Pages 269–293 *in* Ecology and management of Neotropical migratory birds: a synthesis and review of critical issues. *Edited by* T. E. Martin and D. M. Finch. Oxford University Press, New York.

Rottenborn, S. C. 1996. The use of coastal agricultural fields in Virginia as foraging habitat by shorebirds. Wilson Bulletin 108: 783–796.

SAS Institute. 1989. SAS user's guide: Statistics. Release 6.04. SAS Institute, Cary, North Carolina.

Speirs, J. M., and **R. Orenstein.** 1967. Bird populations in fields of Ontario County. Canadian Field-Naturalist 81: 175–183.

Statistics Canada. 1987. Agriculture. Ontario, Catalogue 96-108 edition. Minister of Supply and Services, Canada.

Tucker, G. M. 1992. Effects of agricultural practices on field use by invertebrate-feeding birds in winter. Journal of Applied Ecology 29: 779–790.

Warner, R. E. 1994. Agricultural land use and grassland habitat in Illinois: Future shock for mid-western birds? Conservation Biology 8: 147-156.

Wilson, J. D., R. Taylor, and **L. B. Muirhead.** 1996. Field use by farmland birds in winter: an analysis of field type preferences using resampling methods. Bird Study 43: 320–332.

Yahner, R. H. 1988. Changes in wildlife communities near edges. Conservation Biology 2: 333–339.

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Appendix

Summary table for the 138 species recorded in the study. Frequency and maximum abundance at any one time, and location of the species seen inside or at the edge of cropfields, are given separately for each crop, county and year.

Frequency	■	>75%	(recurrent)
	●	50%-74%	(regular)
	▬	25%-49%	(occasional)
	⬮	<25%	(uncommon)

Maximum abundance: maximum number of individuals per field at any one visit

Location of birds: E=species only seen in field edges
I=species only seen in field interiors
B=birds seen in both edges and field interiors

Example: ⬮ Frequency <25%
E 2 Only seen in field edges, at maximum abundance of 2

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug / Sept.	May	June	July	Aug / Sept	May	June	July	Aug / Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept	May	June	July	Aug./ Sept.
Great Blue Heron	87								● E 2				● E 1												
Ardea herodias	88				● E 1																				
Great Egret	87																								
Ardea alba	88														● E 1										
Striated Heron	87																								
Butorides striatus	88																		● I 1		● E 1				
Black-crowned Night-Heron	87								● I 1																
Nycticorax nycticorax	88																								
Canada Goose	87																							● I 4	
Branta canadensis	88					● B 11	● I 12																		
American Black Duck	87												● E 2												
Anas rubripes	88																								
Mallard	87							● E 1				● I 8	● E 21												
Anas platyrhynchos	88														● E 1			● E 1		● E 1					
Blue-winged Teal	87											● I 2									● E 2				
Anas discors	88		↑																						

Continued

SPECIES	Year	CORN - Essex May	June	July	Aug./ Sept.	CORN - Norfolk May	June	July	Aug./ Sept.	CORN - Niagara May	June	July	Aug./ Sept.	SOYBEAN - Essex May	June	July	Aug./ Sept.	APPLE - Norfolk May	June	July	Aug./ Sept.	GRAPE - Niagara May	June	July	Aug./ Sept.
Turkey Vulture	87								B 1			I 1													E 2
Cathartes aura	88																								
Osprey	87																								
Pandion haliaetus	88								E 1																
Bald Eagle	87																								
Haliaeetus leucocephalus	88						E 2																		
Northern Harrier	87			I 1	I 4				I 1				B 1			I 1	I 1			B 1	E 1			I 1	I 2
Circus cyaneus	88	I 1	I 1		I 1	E 1	E 1		B 1						I 2		I 1	B 2			E 1				
Sharp-shinned Hawk	87				B 1				B 1				I 1				I 1				B 1				
Accipiter striatus	88				E 1		I 1		B 1								I 1	B 1			I 1				
Cooper's Hawk	87																				I 1				
Accipiter cooperii	88								B 1												E 1				
Red-shouldered Hawk	87																								
Buteo lineatus	88																			E 1					
Broad-winged Hawk	87																				E 1				
Buteo platypterus	88														I 1										

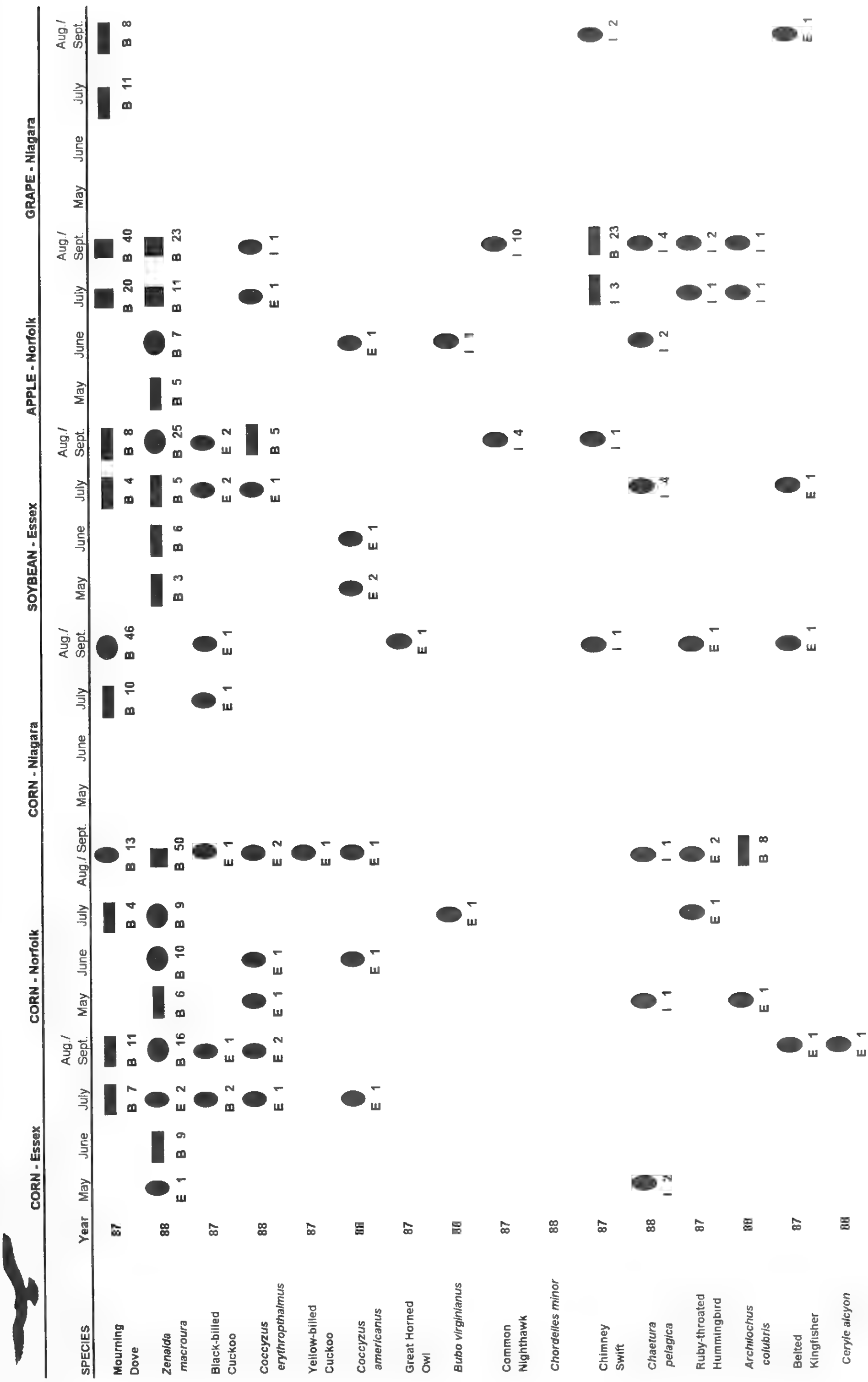
Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Red-tailed Hawk	87											E 1	B 2				I 1			I 1	I 1			B 1	B 1
Buteo jamaicensis	88				E 1												I 1		B 1	E 1	B 1				
American Kestrel	87			E 1	B 2								B 2			E 2	B 2			I 1	B 1			E 1	E 2
Falco sparverius	88	I 1		B 2	B 1		I 1	E 1	B 1								B 1								
Merlin	87								E 1																
Falco columbarius	88																								
Ring-necked Pheasant	87			E 2	I 1												I 1								
Phasianus colchicus	88			I 1	B 4	E 1									B 12	E 8	E 5								
Ruffed Grouse	87																				I 1				
Bonasa umbellus	88								E 3																
Sandhill Crane	87																								
Grus canadensis	88						E 1																		
Black-bellied Plover	87																								
Pluvialis squatarola	88	I 1							E 4																
Killdeer	87			E 1				B 3	E 14			B 3	B 9			B 2	E 2			B 3	E 1			B 10	B 9
Charadrius vociferus	88	B 4	B 3	B 3	E 1	B 3	B 4	B 2	B 10					B 3	B 4	B 2	B 2	B 2	B 2	B 3					

Continued

SPECIES	Year	CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
		May	June	July	Aug./ Sept	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Lesser Yellowlegs	87											I 1													
Tringa flavipes	88																								
Solitary Sandpiper	87																				E 1			B 1	E 1
Tringa solitaria	88																				E 1				
Spotted Sandpiper	87							I 4				I 1				E 2	I 1			I 1				E 4	
Actitis macularia	88	I 2	E 1			B 3	B 1							I 1	B 1										
Upland Sandpiper	87								E 1																
Bartramia longicauda	88																E 1								
Pectoral Sandpiper	87											I 1													E 1
Calidris melanotos	88																								
American Woodcock	87				B 1							B 3	I 1												
Scolopax minor	88								E 1																
Ring-billed Gull	87																								
Larus delawarensis	88	I 1			B 12	I 22	B 4		B 25							E 4	E 3								
Rock Dove	87																			E 1	B 3			B 19	
Columba livia	88					I 2	I 1								I 2				E 2		E 1				

Continued


SPECIES
Year
CORN - Essex
CORN - Norfolk
CORN - Niagara
SOYBEAN - Essex
APPLE - Norfolk
GRAPE - Niagara
May
June
July
Aug./ Sept.
Mourning Dove
Zenaida macroura
Black-billed Cuckoo
Coccyzus erythropthalmus
Yellow-billed Cuckoo
Coccyzus americanus
Great Horned Owl
Bubo virginianus
Common Nighthawk
Chordeiles minor
Chimney Swift
Chaetura pelagica
Ruby-throated Hummingbird
Archilochus colubris
Belted Kingfisher
Ceryle alcyon

Continued

SPECIES	Year	CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
		May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Red-headed Woodpecker	87								E 4											I 1					E 1
Melanerpes erythrocephalus	88								E 1																
Downy Woodpecker	87			E 2	B 1			B 3	B 1			B 1	B 3			E 1	E 2			B 2	B 2			E 1	B 1
Picoides pubescens	88			E 1	E 1		E 1	E 2	B 2						E 3	E 1	E 2	I 1	B 3	B 4	B 5				
Hairy Woodpecker	87								E 1				E 1							I 1	I 1				E 1
Picoides villosus	88																								
Northern Flicker (yellow-shafted)	87							E 1	B 3			E 1	B 2			B 2	E 2			B 4	B 5			B 3	B 6
Colaptes auratus	88		B 1		E 1	E 3	B 3	B 6	B 3						E 1	E 2	E 1	B 2	B 3	B 4	B 4				
Olive-sided Flycatcher	87																								
Contopus borealis	88								E 1																
Eastern Wood-Pewee	87							E 2	E 1				E 2				E 1			E 1	B 1			E 1	B 2
Contopus cooperi	88	E 1			I 1	E 1	E 1	E 1	E 1					E 4			E 1		E 1		E 1				
Yellow-bellied Flycatcher	87								E 1																
Empidonax flaviventris	88																								
Alder Flycatcher	87																								
Empidonax alnorum	88		E 1						E 1					E 1											

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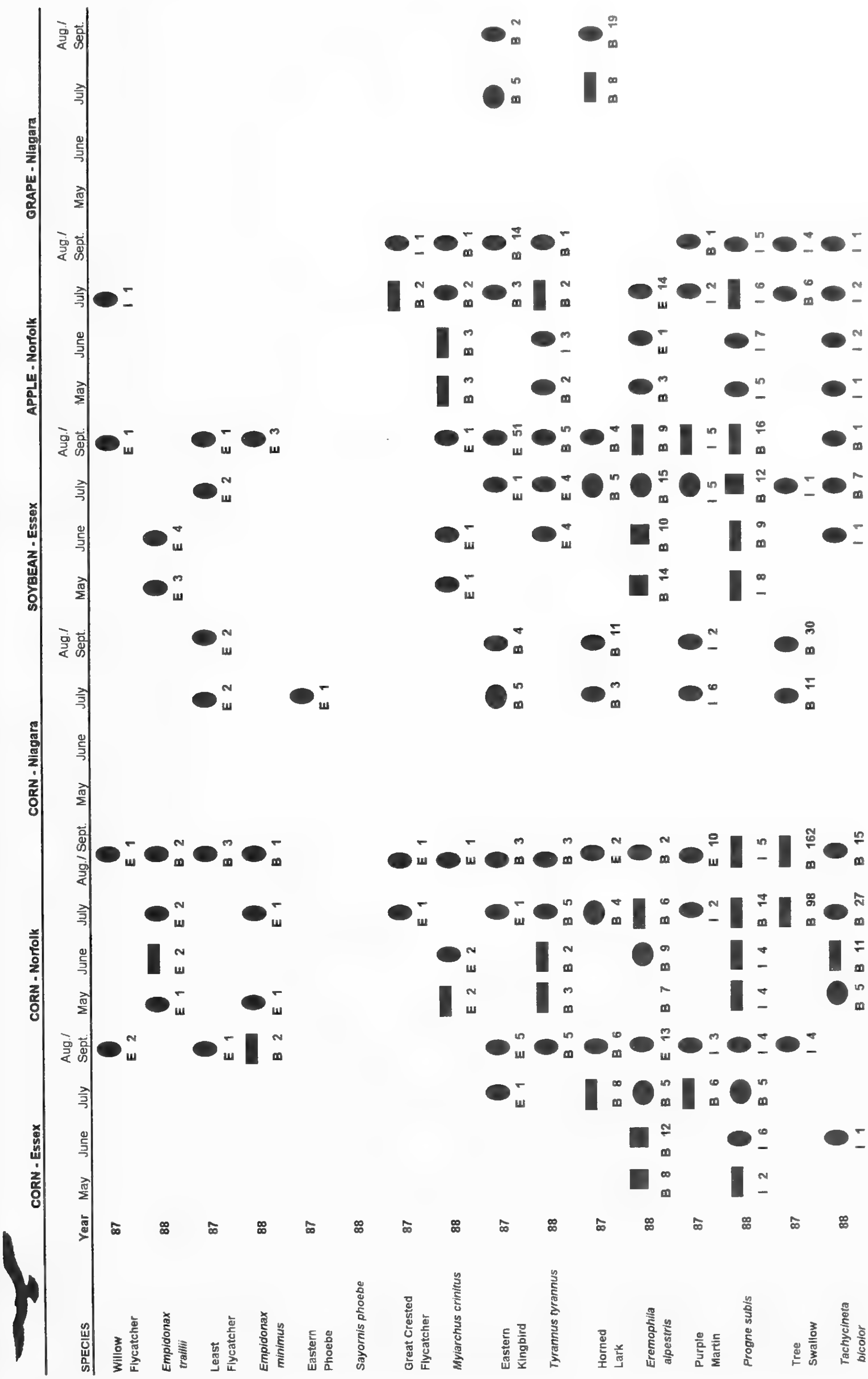
CORN - Essex
CORN - Norfolk
CORN - Niagara
SOYBEAN - Essex
APPLE - Norfolk
GRAPE - Niagara
SPECIES
Year
May
June
July
Aug./ Sept.
Willow Flycatcher
Empidonax traillii
Least Flycatcher
Empidonax minimus
Eastern Phoebe
Sayornis phoebe
Great Crested Flycatcher
Myiarchus crinitus
Eastern Kingbird
Tyrannus tyrannus
Horned Lark
Eremophila alpestris
Purple Martin
Progne subis
Tree Swallow
Tachycineta bicolor

Continued

SPECIES	Year	CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
		May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept	May	June	July	Aug./ Sept.
Northern Rough-winged Swallow	87			● I 2				● B 11								● I 2	● I 1			● E 2	● I 2				
Stelgidopteryx serripennis	88	● I 3	● B 2	● I 1			● I 2	● I 1	● E 4					▬ E 3	● B 2	● I 1			● I 2	● I 1					
Bank Swallow	87			● I 15	● I 59			▬ B 150	▬ B 258				● B 60			● I 2	● I 16			● B 73	● B 194				● E 1
Riparia riparia	88	▬ I 1		● I 4	● I 3	● I 64	● I 25	● B 189	● B 415					▬ I 3	● B 9	▬ B 14	● I 22	● I 4	● I 2	▬ I 7	▬ I 114				
Cliff Swallow	87			● I 1	● I 2			● I 3	● I 4							● I 1	● I 2				● I 1				
Petrochelidon pyrrhonota	88				● I 1	● I 2	● I 9	● I 6	● B 4						● I 2	● I 1	● I 2								
Barn Swallow	87			▬ B 13	● I 9			▬ B 18	▬ B 20			▬ I 34	▬ B 31			▬ B 13	● B 13			▬ B 15	● B 27			● I 11	● B 40
Hirundo rustica	88	▬ I 7	▬ B 6	▬ B 17	● B 10	▬ B 16	▬ B 22	▬ B 21	● B 30					● I 8	▬ I 10	▬ I 19	▬ B 36	● B 5	● I 8	● I 6	● I 14				
Swallow Species	87			● I 1																					
	88																								
Blue Jay	87			● E 2	● B 5			● B 5	● B 2			● B 2	▬ B 5							● B 3	▬ B 2				● B 7
Cyanocitta cristata	88	● E 1	● E 2	● E 1	● E 5	▬ B 4	● E 2	● E 2	● E 2						● E 1	● E 1	▬ E 4	● B 3	● B 2	● B 2	▬ B 3				
American Crow	87			● E 3				● B 2	● E 8			● E 3	● E 7			● E 4	● E 2			● B 7	● B 7			● B 2	● B 1
Corvus brachyrhynchos	88	▬ I 4	● B 2			▬ B 4	● I 3	● E 5	● B 11					● B 6	▬ B 3	▬ B 6	● E 8	● B 4	● B 6	● B 8	● B 10				
Black-capped Chickadee	87							● E 2	● B 4			▬ B 4	▬ B 11							● B 6	▬ B 7			● E 4	● B 6
Poecile atricapillus	88					● E 1		● E 2	● B 8									● B 2	▬ B 4	▬ B 6	▬ B 10				

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Red-breasted Nuthatch	87				E 1																				
Sitta canadensis	88				E 1												E 2			E 2	E 1				
White-breasted Nuthatch	87												E 1							B 1	E 1				E 1
Sitta carolinensis	88							E 2	E 1									E 1	E 1	E 1	E 5				
Carolina Wren	87							E 1																	
Thryothorus ludovicianus	88																								
House Wren	87								E 1			E 1	E 1			E 1	E 1			B 4	B 2			E 2	B 4
Troglodytes aedon	88				E 1	E 1	E 1	E 4	E 5						E 4	E 2	B 2		B 2	B 2	B 1				
Winter Wren	87								I 1																
Troglodytes troglodytes	88																								
Golden-crowned Kinglet	87												E 2												
Regulus satrapa	88																								
Ruby-crowned Kinglet	87												E 3												
Regulus calendula	88				E 1																				
Blue-gray Gnatcatcher	87																								
Polioptila caerulea	88					E 1															E 1				

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Eastern Bluebird	87											E 1								B 10	B 13			B 4	B 5
Sialia sialis	88					B 1	B 6											B 4	B 5	B 7	B 10				
Veery	87								E 3																
Catharus fuscescens	88																E 1				E 1				
Gray-cheeked Thrush	87																								E 1
Catharus minimus	88																								
Swainson's Thrush	87				E 1				E 1								E 1								I 1
Catharus ustulatus	88				E 1				E 1								E 4								
American Robin	87			B 8	B 5			B 12	B 12			B 102	B 29			B 9	B 18			B 41	B 27			B 33	B 65
Turdus migratorius	88	B 4	B 6	B 11	B 7	B 11	B 9	B 39	B 13					E 4	B 4	B 8	B 11	B 10	B 7	B 43	B 35				
Gray Catbird	87			E 2				B 2	B 3			E 1	B 2			B 1	E 1			B 1	E 1			B 2	B 2
Dumetella carolinensis	88	E 1	E 2	E 2	E 3	B 5	B 3	B 4	B 4						E 1	B 3	E 1	E 2	B 2	E 2					
Northern Mockingbird	87																							I 1	I 2
Mimus polyglottos	88																		I 1	I 1					
Brown Thrasher	87							E 1	E 1			E 1	B 2			I 2	B 1			I 1				E 1	
Toxostoma rufum	88		E 1	E 2	E 2	E 1	B 2	B 3							E 1		I 1	B 1	B 2	E 2					

Continued

SPECIES	Year	CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
		May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Cedar Waxing	87			● E 1	● E 3			● E 3	▬ E 27			▬ E 6	▬ B 6			▬ E 4	▬ E 11			■ B 5	■ B 16			● E 2	● B 1
Bombycilla cedrorum	88			● E 1	● E 2	● E 2	▬ E 5	● E 6	● B 31							▬ E 2	▬ E 5	▬ B 18	▬ B 4	▬ B 4	● B 34				
European Starling	87			▬ B 26	● B 7			▬ B 490	▬ B 1980			▬ B 14	● B 108			● E 16	▬ B 18			▬ B 40	▬ B 144			▬ B 20	▬ B 88
Sturnus vulgaris	88	● B 2	● B 26	▬ B 18	● B 80	■ B 17	■ B 85	● 80	▬ B 115					● E 6	▬ B 42	▬ E 28	● E 22	● B 23	● B 112	▬ B 105	▬ B 219				
Yellow-throated Vireo	87																				● I 1				
Vireo flavifrons	88																		● E 1						
Warbling Vireo	87												● E 1												● E 1
Vireo gilvus	88					● E 2	● E 1	▬ B 2	● E 1								● E 1								
Philadelphia Vireo	87																								
Vireo philadelphicus	88																● E 1								
Red-eyed Vireo	87								● E 1								● E 1				● E 1				
Vireo olivaceus	88				● E 1	● E 1	● E 1	● E 1	● E 1					● E 1		● E 1	● E 4	● E 1	● E 3	● E 1	● E 1				
Blue-winged Warbler	87								● E 1				● E 1				● E 1								
Vermivora pinus	88				● E 1	● E 1			● E 1								● E 1				● E 1				
Tennessee Warbler	87			● I 1	● B 2				● B 1				● E 1			● E 1	● E 1								
Vermivora peregrina	88			● E 1	● B 2				● E 2								● B 1				● I 1				

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug / Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Nashville Warbler	87				B 1				E 2				B 1												
Vermivora ruficapilla	88				E 1				B 1								E 1				I 1				
Yellow Warbler	87			B 5	B 3			B 4	B 6			B 4	B 3			B 4	B 2			I 1					I 1
Dendroica petechia	88				B 2	E 13	B 14	B 22	B 19						E 1		B 2	E 1	I 1		I 1				
Chestnut-sided Warbler	87				E 1				E 1				B 1							I 1					E 1
Dendroica pensylvanica	88							E 1	E 1								E 3	E 1	E 1	E 1	E 1				
Magnolia Warbler	87				B 2								B 2				E 1				I 1				
Dendroica magnolia	88				E 2				B 3								E 4				I 1				
Cape May Warbler	87								B 5				B 3								I 2				E 1
Dendroica tigrina	88				E 1				B 6								E 2				B 1				
Black-throated Blue Warbler	87				E 1				E 1																
Dendroica caerulescens	88								E 1								E 1				I 1				
Yellow-rumped Warbler	87								B 1				B 5				B 1								
Dendroica coronata	88				E 1	E 1			B 1												I 1				
Black-throated Green Warbler	87																								
Dendroica virens	88				E 1	E 1											E 2								

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept	May	June	July	Aug./ Sept	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug / Sept.	May	June	July	Aug./ Sept.
Blackburnian Warbler	87																								
Dendroica fusca	88																E 1								
Pine Warbler	87								E 1				E 1								I 10				
Dendroica pinus	88					E 1	E 1												E 1	E 1	B 3				
Palm Warbler	87				I 1				I 1				E 2				I 1								
Dendroica palmarum	88				B 6												B 2				I 2				
Bay-breasted Warbler	87				E 1				E 1				E 2												I 1
Dendroica castanea	88					E 1			E 2								E 1				E 1				
Blackpoll Warbler	87				E 1												E 1								
Dendroica striata	88				B 4												E 4								
Black-and-White Warbler	87				E 1				E 1								E 2								E 1
Mniotilta varia	88																E 2								
American Redstart	87							E 1	B 3				E 2				E 1								
Setophaga ruticilla	88				E 1	E 1	E 1	E 1	B 3								E 4				I 1				
Ovenbird	87				E 1				B 1				E 1												
Seiurus aurocapillus	88								B 1								E 2				E 1				

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Northern Waterthrush	87				● E 1				● B 1							● E 1	● B 1								
Seiurus noveboracensis	88								● B 2																
Mourning Warbler	87								● E 1				● I 1												
Oporornis philadelphia	88																● E 1								
Common Yellowthroat	87				● B 2			● B 3	● B 3			● I 1	▬ E 3			● E 2	● B 1								● B 1
Geothlypis trichas	88				● E 2	▬ B 6	▬ B 12	● B 7	● B 7					● E 1	● E 1		● E 2				● B 4				
Wilson's Warbler	87								● B 1				● B 1												● I 1
Wilsonia pusilla	88				● E 1				● B 1								● E 1								
Canada Warbler	87												● E 1												
Wilsonia canadensis	88						● E 1		● E 1								● E 1								
Warbler Species	87				B 7				B 7				E 4				B 2				I 1				I 1
	88				B 2				E 2								B 12				B 2				
Scarlet Tanager	87																								
Piranga olivacea	88																	● E 1	● E 1						
Northern Cardinal	87			● E 1	● E 1			● B 6	▬ B 3			▬ B 2	● B 3			● B 1	● E 1			● B 1	● 2			● E 1	● B 2
Cardinalis cardinalis	88	● E 2	● E 1		▬ B 4	▬ E 3	▬ B 3	▬ E 3	▬ B 4						● E 1	▬ B 2	● B 3	● E 1	● B 3	● B 2	● 2				

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Rose-breasted Grosbeak	87												● B 6							● B 2	● B 2				● I 1
Pheucticus ludovicianus	88				● E 1	● E 2		● E 4	● E 1												● E 1				
Indigo Bunting	87			▬ B 3	▬ B 6			● B 5	● B 4			● B 3	▬ B 4			● E 3	▬ B 4			● B 2	● 1			● E 1	● E 1
Passerina cyanea	88	● B 3	▬ B 5	● B 3	▬ B 5	▬ E 1	▬ E 3	● B 5	● B 7					▬ E 2	▬ E 4	● E 6	▬ B 8	● E 3	● B 3	● B 4	● B 1				
Dickcissel	87																								
Spiza americana	88				● E 1																				
Eastern Towhee	87																			● B 3	● B 2				
Pipilo erythrophthalmus	88																	● B 4	● B 2	▬ E 2	● E 2				
Chipping Sparrow	87			● B 2	● B 14			● B 5	● B 5			● B 2	▬ B 4			▬ B 5	▬ B 7			■ B 22	■ B 142			■ B 26	● B 13
Spizella passerina	88	● E 1	● E 1	● B 7	● B 3	● B 4	▬ B 4	● 6	▬ B 6					● E 2	● B 7	■ B 4	▬ B 3	■ B 18	■ B 13	■ B ·164	■ B 217				
Clay-colored Sparrow	87																								
Spizella pallida	88				● E 1																				
Field Sparrow	87							● I 1	● E 1			● E 1	● B 5				● I 2			● B 7	▬ B 38			● B 3	● I 4
Spizella pusilla	88							● E 1										▬ B 3	● B 2	▬ B 7	▬ 8				
Vesper Sparrow	87			● B 3	● B 5			▬ I 4	● B 4			● B 2	▬ B 6			● B 4	▬ B 2			▬ B 4	● B 2			● B 4	● B 3
Pooecetes gramineus	88	■ B 4	▬ B 4	● B 4	● B 2	● B 1	▬ B 4	● B 1						■ B 2	● B 4	● B 3	▬ B 5	● B 2	▬ B 2	▬ B 2	● B 2				

Continued

SPECIES	Year	CORN - Essex May	CORN - Essex June	CORN - Essex July	CORN - Essex Aug./ Sept.	CORN - Norfolk May	CORN - Norfolk June	CORN - Norfolk July	CORN - Norfolk Aug./ Sept.	CORN - Niagara May	CORN - Niagara June	CORN - Niagara July	CORN - Niagara Aug./ Sept.	SOYBEAN - Essex May	SOYBEAN - Essex June	SOYBEAN - Essex July	SOYBEAN - Essex Aug./ Sept.	APPLE - Norfolk May	APPLE - Norfolk June	APPLE - Norfolk July	APPLE - Norfolk Aug./ Sept.	GRAPE - Niagara May	GRAPE - Niagara June	GRAPE - Niagara July	GRAPE - Niagara Aug./ Sept.
Savannah Sparrow	87			B 3	B 3			B 23	B 22			B 19	B 28			B 5	B 6			B 9	B 82			B 11	B 5
Passerculus sandwichensis	88	I 2	B 4	B 4	B 1	B 8	B 22	B 18	B 13					B 6	B 4	B 3	B 4	B 9	B 13	B 41	B 26				
Song Sparrow	87			B 13	B 11			B 16	B 15			B 21	B 27			B 14	B 13			B 11	B 6			B 9	B 4
Melospiza melodia	88	B 10	B 11	B 10	B 9	B 13	B 13	B 18	B 19					B 7	B 14	B 10	B 9	B 7	B 11	B 13	B 11				
Lincoln's Sparrow	87								B 1				E 1				I 1								
Melospiza lincolnii	88																								
Swamp Sparrow	87								B 1				B 6												
Melospiza georgiana	88					E 1	E 1	B 18	B 28																
White-throated Sparrow	87				E 1								B 12				E 1								
Zonotrichia albicollis	88				E 1												E 2								
White-crowned Sparrow	87																								
Zonotrichia leucophrys	88					E 1												E 2							
Sparrow Species	87								I 2			I 1	B 6							B 14	B 99				I 2
	88				E 1		E 1	I 2									I 1	I 1	I 1	B 7	B 34				
Dark-eyed Junco	87				I 1								E 2												
Junco hyemalis	88																								

Continued

		CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
SPECIES	Year	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Bobolink	87			● E 11				● B 12	● B 18			● B 2	▬ B 56			▬ B 20	▬ B 11			● B 20	● I 1				● I 5
Dolichonyx oryzivorus	88	▬ B 2	▬ B 7		● E 1	▬ B 2	● E 1	● B 8	● B 21					● I 1	● E 2	● E 6	● B 2	● B 6		● B 1					
Red-winged Blackbird	87			▬ B 17	● B 5			● B 372	● B 28960			■ B 125	● B 1014			● B 18	● B 4			● E 1				● B 69	● B 6
Agelaius phoeniceus	88	▬ E 3	● B 14	● B 181	▬ B 250	■ B 32	■ B 106	■ B 384	■ B 156					● B 4	● B 37	▬ B 48	▬ E 30	● B 2	● B 1		● I 18				
Eastern Meadowlark	87											● I 1	● E 1											● I 3	● B 2
Sturnella magna	88						● I 1	● E 1							● I 1			● I 1							
Rusty Blackbird	87												● I 1												
Euphagus carolinus	88																								
Brewer's Blackbird	87																								
Euphagus cyanocephalus	88																		● I 1						
Common Grackle	87			▬ B 19	● B 4			● B 100	● B 30			● B 36	▬ B 110			● B 15	● I 1			● B 3	● I 200			● B 8	● B 3
Quiscalus quiscula	88	■ B 10	● B 26	● I 31	● B 80	■ B 23	■ B 39	● B 58	▬ B 152					■ B 20	● B 21	● E 2	● B 45	▬ B 6	▬ B 4	● B 14					
Brown-headed Cowbird	87			● E 1	● B 1			● I 4	● E 100			▬ B 7	● B 10			● B 5	● E 2			● B 4	● B 2			● B 2	● B 1
Molothrus ater	88	▬ E 2	● E 7	● E 3	● E 1	■ B 5	● B 10	▬ B 7	● B 30					▬ E 3	▬ B 6	● E 2	● B 2	● B 5	● B 6	▬ E 7	● I 6				
Orchard Oriole	87																				● E 1				
Icterus spurius	88					● E 1																			

Continued

SPECIES	Year	CORN - Essex				CORN - Norfolk				CORN - Niagara				SOYBEAN - Essex				APPLE - Norfolk				GRAPE - Niagara			
		May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.	May	June	July	Aug./ Sept.
Baltimore Oriole	87				B 4			B 10	B 4			B 2	B 2			E 4	E 1			I 1	B 6			E 2	B 7
Icterus galbula	88		E 2	E 2	E 3	E 1	B 2	E 6	B 3					E 1	E 2	B 2	E 1	B 2	I 2	E 1	E 4				
Purple Finch	87			I 1																					
Carpodacus purpureus	88																								
House Finch	87			E 1				E 1	E 1				E 2			E 3	E 4			B 3	I 6			B 33	B 58
Carpodacus mexicanus	88					E 1	E 4	B 6	B 4					E 1	B 1	E 3	B 2	B 1	B 15	B 7	B 10				
American Goldfinch	87			B 4	B 4			B 2	B 21			B 10	B 65			B 2	E 4			B 6	B 9			B 16	B 8
Carduelis tristis	88	E 3	E 3	B 1	B 3	E 3	E 3	B 5	B 7					E 1	B 7	E 3	B 7	B 2	B 6	B 5	B 8				
House Sparrow	87			B 6	B 38			B 19	B 215			B 55	B 74			B 22	B 53			B 10	B 14			B 46	B 59
Passer domesticus	88	E 3	B 3	B 11	B 64	E 3	B 6	B 18	B 12					B 2	B 7	B 12	B 12		E 2	I 3	B 19				

Status of the Tall Bugbane, *Cimicifuga elata* (Ranunculaceae), in Canada

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Penny, Jenifer L., and George W. Douglas. 1999. Status of Tall Bugbane, *Cimicifuga elata* (Ranunculaceae), in Canada. Canadian Field-Naturalist 113(3): 461–465.

In British Columbia, *Cimicifuga elata* is restricted to eight recently verified sites in the Chilliwack River valley. Population sizes are relatively small, ranging from a single plant to 63 plants, making this species susceptible to low genetic diversity. Suitable habitat for *C. elata* in the Chilliwack River valley appears to be mature, mixed Cedar-Hemlock-Maple stands, Douglas-fir-Maple stands, and some deciduous stands. However, most of the range of this species has been extensively converted through logging to young forest. Young stands that develop following harvest do not contain suitable habitat to sustain *C. elata*, therefore, current forest harvest practises threaten this species. *Cimicifuga elata* has reproductive limitations that make colonization into new sites difficult. It is relatively much less attractive to pollinators than other flowering plants, and lacks any effective seed dispersal mechanism. Considering these biological limitations, the uncertainty of the effect of logging practices on this species, and the small population sizes, the future of *C. elata* is uncertain in the Chilliwack River valley.

Key Words: Tall Bugbane, *Cimicifuga elata*, endangered, distribution, population size, British Columbia.

Tall Bugbane (*Cimicifuga elata* Nutt.) is one of fifteen, circumboreal *Cimicifuga* species (Hay and Beckett 1978). Six of these species occur in North America, two on the west coast, including *C. elata*, and four on the east coast and in the southern U.S. (Evans 1992). *Cimicifuga racemosa*, an eastern species, is the only common species found in North America. The remaining nine species of *Cimicifuga* occur in Europe and the Far East.

Cimicifuga elata is a perennial, understorey plant that stands 1 to 2 m tall (Figure 1; Hitchcock et al. 1964). Stems are branched above with glandular swellings at leaflet and stem joints, and leaves are large, thin, and bi-ternate. The 9–17 leaftlets are cordate to ovate, often palmate, and 5–7-lobed (usually 3-lobed) with serrate to dentate margins. Leaves are rough-hairy on top, and smooth below. The plant is finely pubescent, and somewhat glandular above with a dark, tuberous horizontal rhizome, up to 10.2 cm long and 2.5 cm in diameter. The inflorescence is a simple to compound raceme (sometimes paniculate) with 50 to 900 small, white, closely-crowded flowers (Pellmyr 1986). Individual flowers are radially symmetrical and apetalous. Pedicels are shorter than the flowers, and sepals are white or pinkish, falling off at once. When the sepals fall away, only the stamens and pistils remain, and the inflorescence appears like a bottle brush. Fruits are follicles, 9 to 12 mm long, subsessile, born singly in the upper flowers of the raceme, but in two's, and rarely three's, in the lower ones. Each follicle contains approximately 10, red to purple-brown seeds. In the vegetative form, *Cimicifuga elata* may be confused with a few other understorey plants, such as Baneberry (*Actaea rubra*) [Nomenclature follows Douglas et al. 1989–1991], however, when flowering, it is very distinctive.

Editor's note: Although the format of this paper is in COSEWIC style, a status for this species has not been considered by COSEWIC at the time of submission, and **no designation has yet been made by COSEWIC.**

Distribution

Cimicifuga elata occurs from the Chilliwack River valley in south-western British Columbia, through western Washington, to as far south as Ashland in southwestern Oregon. *Cimicifuga elata* occurs entirely west of the Cascade Mountains in British Columbia and Washington, but occurs within these mountains in southern Oregon. In British Columbia, *C. elata* is only found sporadically in the Chilliwack River valley (Figure 2).

Habitat

Cimicifuga elata grows in shady, moist, mature (70-150 y-old) Western Red Cedar-Western Hemlock forests (*Thuja plicata-Tsuga heterophylla*), commonly in Red Cedar-Swordfern-Vanilla Leaf (*Thuja plicata-Polystichum munitum-Achlys triphylla*) communities. *Cimicifuga elata* is also found in mixed Douglas-fir-Big-leaf Maple (*Pseudotsuga menziesii-Acer macrophyllum*, and in predominately deciduous stands. The deciduous species are extremely important, as they provide the appropriate

FIGURE 1. Illustration of *Cimicifuga elata*. Line drawing by Jane Lee Ling in Douglas et. al (1998).

balance of shade and light, and moisture retention. Common associated species include Thimbleberry (*Rubus parviflorus*), Devils' Club (*Oploplopanax horridus*), Vine Maple (*Acer circinatum*), Spreading Wood Fern (*Dryopteris expansa*), Youth-on-age (*Tolmeia menziesii*), Red Elderberry (*Sambucus racemosa*), Enchanter's-nightshade (*Circea alpina*), and Wild Ginger (*Asarum caudatum*). Sites are characterized by 15–35° slopes with north, southwest, and south aspects.

Cimicifuga elata has been observed in managed stands that contain clear-cuts, mature second growth forests, and deciduous stands. Individuals of *C. elata* have been observed on road-cuts and in clear-cuts where there is increased light availability, and freshly disturbed mineral soil increasing the chances for seedling establishment. Seedlings in these sites display increased vigor over understorey individuals of *C. elata* and were likely derived from parent populations on forested slopes above. Road-cuts and clear-cuts mimic natural canopy openings that are likely required for flowering, fruiting and establishment of *C. elata* into new sites. However, several years following clear-cuts, the dense shrub growth that prevails likely outcompetes *C. elata*. For this reason individuals will not persist in sites that are extensively clear-cut. During field work conducted by the Conservation Data Centre in 1997, *C. elata* was found to be more common in areas that were not extensively clear-cut, but that instead, had a patchwork of mature mixed-forest, deciduous stands, small clear-cuts, and road-cuts. In Washington, this species is likewise mainly associated with mature or old-growth coniferous or mixed-forest, but is also observed at forest margins and on road-cuts.

Biology

There is no information available on the biology of *Cimicifuga elata* in British Columbia. However, in Washington and Oregon where this species is more abundant, research has focussed on pollination ecology (Pellmyr 1985a, 1985b, 1986), and on population genetic structure with implications associated with its rarity (Evans 1993). There have also been studies on the presence of active compounds of pharmacological use in species of *Cimicifuga*, particularly those in the Far East (Shibata et al. 1980).

Phenology

Young plants of *Cimicifuga elata* emerge in the spring, produce buds in late spring, and flower mid-June to August. In experiments, Kaye and Kirkland

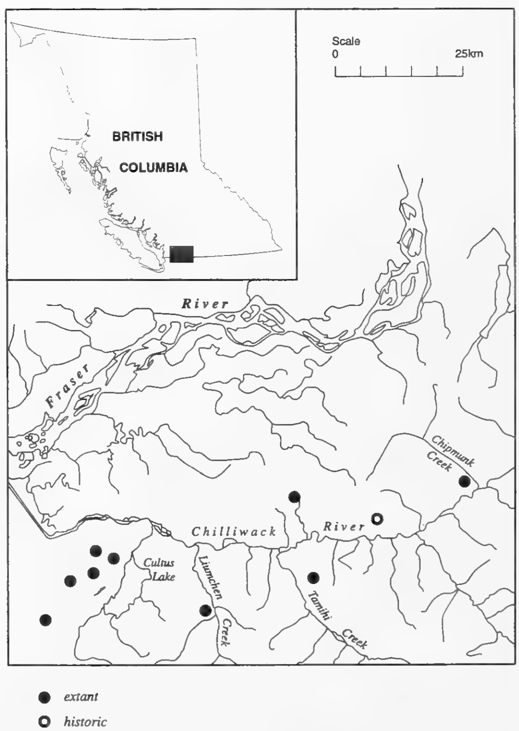

FIGURE 2. Distribution of *Cimicifuga elata* in British Columbia.

(1994) showed that seeds required cold-stratification for germination and that percentage germination was low. Seeds are heavy, have no special dispersal mechanism, and are dispersed within a few meters of the parent plant (Kaye and Kirkland 1994; Wentworth 1996). In growth experiments on *C. elata* using ample light, plants grew to reproductive size in three years (Anonymous 1996). Under less ideal conditions, time to reproductive size could be six years.

Pollination Biology

This species is pollinated by bumblebees, solitary bees, the introduced honeybee, and syrphid flies. *Cimicifuga elata* is poorly adapted to out-crossing, is a poor competitor for pollinators, and is self-compatible. Consequently, flowers of *C. elata* are not showy, nectarless, without markings to guide pollinators, and without special structures to apply pollen to bodies of pollinators, all features associated with self-pollination (Evans 1992). A reduced number of staminodia also leads to selfing (Pellmyr 1985b). Usually staminodia are completely absent from this species (Evans 1992). In addition, *C. elata* occurs in habitats that contains few attractive-flowering associate species, and therefore, cannot benefit from their increased ability to attract pollinators. Pollination is geitonogamous, or flower to flower on the same plant, which ensures pollination in a single visit and successful selfing (Pellmyr 1986). Flowering occurs sequentially within the raceme, with individual flowers blooming at different times, extending the flowering period, thus, unlike previously mentioned characteristics, maximizes the chance of cross-pollination. Evans (1992) found that the blooming period varied from 19 to 47 days, and that, on average, the flowering ratio was 10 out of 23 flowers per inflorescence.

Population Size and Trends

Intensive inventory work done by the British Columbia Conservation Data Centre on a number of taxa, including *Cimicifuga elata* (Douglas and Illingworth 1997; Douglas and Ryan 1998; Jamison and Douglas 1998; Penny and Douglas 1998), has vastly increased our knowledge of the distribution of these taxa. *Cimicifuga elata* is now known from ten sites, whereas previously it was known from only two sites.

There are eight recently verified sites with populations of *Cimicifuga elata* in the Chilliwack River valley. Populations are relatively small, ranging from a single plant to 63 plants (Table 1). Two records for this species have not been verified recently; one, the Chilliwack River valley, an historic record, that is too vague to verify, while the other, Liumchen Mountain , a record from 1957, likely represents an extirpated site for *C. elata*. Liumchen Mountain has been extensively converted to young forest. Another area extensively clear-cut in recent years is Cheam Mountain, where *C. elata* has been reported in the past, and now persists in small numbers (only a single plant was observed in 1997 by Fontaine and Hartwell (Table 1)). The original observation at this site reported several plants in a clear-cut. In the Chilliwack river valley, *Cimicifuga elata* is never found in dense populations, but rather, is only sparsely distributed over a limited area.

Limiting Factors

Cimicifuga elata has both intrinsic biological limitations, and an uncertain future under current logging regimes in the Pacific Northwest. Populations of *C. elata* are small, and sporadically distributed over the landscape. *Cimicifuga elata* is relatively much less attractive to pollinators than other flowering plants, and therefore, receives less pollinator visits. Furthermore, this species. lacks a specialized seed dispersal mechanism. These two factors potentially limit its reproductive success. As a result, extremely small populations exist in the Chilliwack valley. With small population size comes the threat of low genetic diversity limiting the ability of the species to persist.

In addition to these biological concerns, the increasingly fragmented landscapes of the forests of the Pacific Northwest threaten the persistence of *C. elata*. Natural processes, such as fire and tree disease, that create small canopy gaps which likely allow *C. elata* to flower and establish into new sites are less frequent in managed forests (Anonymous 1996). Stands managed with relatively small canopy gaps which emulate natural canopy openings may be useful in conservation of this species. The large scale of the current harvest regime, however, which has resulted in large tracks of unsuitable habitat for *C. elata* will most certainly prevent reproduction and establishment in this species. Kaye and Kirkland (1994) found that populations of *C. elata* were notably absent from young, 15-30 year-old managed stands. This was corroborated by field work done by the Conservation Data Centre in British Columbia. In one site where the forests had been extensively clear-cut, an observer had noted *C. elata*. It had, at first, survived the clear-cut, but several years later when a Conservation Data Centre crew searched for it, it was not found. *Cimicifuga elata* had apparently disappeared from the locality. This suggests that individuals of this species did not survive the early stages of forest development at this site, during which time there is excessive competition. Furthermore, re-colonization into these sites when suitable conditions eventually return may be unlikely due to a lack of near-by seed sources, or the limited dispersal ability of this species. Clearly, both mature forest (seed source for *C. elata*) and safe sites (forest openings) in close proximity to the seed source are required for successful propagation.

TABLE 1. Localities and population data for *Cimicifuga elata* in Chilliwack, British Columbia.

	Locality	Last observation	Collector	Number of Plants/area
1	Chilliwack River	1901	J. Macoun	unknown
2	Liumchen Mountain	1957	K. Beamish	unknown
3	Vedder Mountain, NW slope, Parmenter Road junction	1997	J. Penny & S. Hartwell	12 plants/0.1 ha.
4	Vedder Mountain, N slope	1997	M. Fontaine & S. Hartwell	29 plants/0.5 ha.
5	Vedder Mountain, NE end, above N end of Cultus Lake	1996	G. Douglas & J. Penny	54 plants/5-6 ha.
6	Vedder Mountain, SE slope, above S end of Cultus Lake	1997	M. Fontaine & S. Hartwell	63 plants/4 ha.
7	Vedder Mountain, SW slope	1988	R. Scagel	unknown
8	Elk Mountain	1997	J. Penny & S. Hartwell	15 plants/0.25 ha
9	Tamihi Creek, E of	1997	J. Penny & S. Hartwell	7 plants/0.1 ha.
10	Cheam Mountain/Chipmunk Creek	1997	M. Fontaine & S. Hartwell	1 plant

Special Significance of the Taxon

Cimicifuga elata populations in British Columbia represent the northern-most limit of the species in its overall distribution in the Pacific Northwest. Given this, populations of *C. elata* in British Columbia may be genetically distinct from populations in the center of the distribution of this species. A genetic study done on seven populations of *C. elata* in Washington and Oregon revealed that the population representing the most southern extent of this species was genetically distinct from the rest of the localities (Evans 1993). Another issue surrounding the genetics of this species is that the relatively small and sporadically distributed populations may possess low genetic diversity and be subject to in-breeding depression, which threatens the long-term persistence of this species. Concern about this issue led to a study on allozyme variation, which revealed that allozyme variation was not as low in *C. elata* as suggested by principles of genetic theory. However, as long as forest harvest continues, the demography and genetic structure of this species will need to be closely monitored for changes that may have repercussions on its long term persistence.

As is the case with other species of *Cimicifuga* being investigated for pharmacological value (Shibata et al. 1980), *C. elata* contains active medicinal ingredients. "Black cohosh," as it is known in the herbal trade, is considered one of the most useful medicinal plants of the Pacific Northwest. It is used as an anti-inflammatory, a peripheral vasodilator, an antispasmodic, a sedative, and an estrogenic (Moore 1993). Despite the medicinal properties, *C. elata* is not well known in the horticultural trade (Wentworth 1996) as are its eastern North American counterpart, *C. racemosa* and the Japanese species of *Cimicifuga*.

From an evolutionary standpoint, *Cimicifuga* species represent a relatively primitive and taxonomically isolated genus within the Ranunculaceae (Pellmyr 1985a). Studies on the plant and pollinator interactions in *Cimicifuga* species can help reveal some information on the evolution of the earliest, herbaceous flowering plants. *Cimicifuga elata* was likely part of the flora of the Pacific Northwest in the Miocene Epoch, 7 to 26 million years before present (Alverson 1986). Both out-crossing and selfing characteristics are present in *C. elata*. The overall evolutionary trend, however, appears to be toward selfing.

Protection

The British Columbia Conservation Data Centre has ranked *C. elata* as S1 and placed it on the Ministry of Environment, Lands and Parks Red list, the most critical category for rare vascular plants in the province (Douglas et al. 1998). The S1 rank, a Nature Conservancy of the United States designation, is given to taxa which are "critically imperiled because of extreme rarity with five or fewer extant occurrences or very few remaining individuals or because of some factor(s) making it especially vulnerable to extirpation or extinction."

Cimicifuga elata is rare throughout its entire range. It has been globally ranked by The Nature Conservancy of the United States as "G2," or "imperiled because of rarity (typically with 6–20 extant sites) or because of some factor(s) making it vulnerable to extirpation or extinction." It is considered threatened by the Washington Natural Heritage Program and threatened or endangered by the Oregon Natural Heritage Program (Wentworth 1996).

There is currently no legislation which specifically protects *C. elata* in British Columbia. The B.C. Forest Practices Code may protect some populations if *C. elata* becomes designated as a *Managing Identified Wildlife* species. In this case, managed reserves on forest lands could be established which take the habitat requirements of this species into consideration, while still allowing some forest harvest. However, at this time, there is little protection for the populations of *C. elata*. None of the populations are found in ecological reserves or parks. However, two small, B.C. Forest Service reserves exist on Mountain Vedder, one a small "wildlife tree patch," and the other, a "visual landscape" reserve, which afford some protection.

Evaluation of Status

Cimicifuga elata has an extremely restricted range in Canada and is rare throughout its entire range. It is known only from eight extant sites in the Chilliwack valley in British Columbia where populations are relatively small, consisting of few to 63 plants. Only three of the eight extant sites have viable population sizes and the species appears to have limited dispersal ability. Furthermore, the region in which it occurs is under heavy logging pressure, and it is not known how vulnerable *C. elata* is to forest practices. It is likely that large scale clearcutting is not consistent with a sound management approach for this species. For these reasons, the British Columbia Conservation Data Centre and the authors recommend that *Cimicifuga elata* be designated as an endangered taxon in Canada.

Acknowledgments

We thank Jane Wentworth from the Washington Natural Heritage Program for coming to Canada in September 1996 and helping to relocate the first plants of *Cimicifuga elata* to be seen in British Columbia since 1957. We also thank Sharon Hartwell and Marie Fontaine for their participation in locating new sites of *C. elata* during the 1997 field work.

Literature Cited

Alverson, E. 1986. Status report on *Cimicifuga elata*. Washington Natural Heritage Program. Olympia, Washington. 16 pages.

Anonymous. 1996. Conservation strategy *Cimicifuga elata* tall bugbane. United States Department of Agriculture, United States Department of the Interior Bureau of Land Management and United States Army Corps of Engineers. Eugene, Oregon. 44 pages.

Douglas G. W., and **J. M. Illingworth.** 1997. Status of the White-top Aster, *Aster curtus* (Asteraceae), in Canada. Canadian Field-Naturalist 111: 622–627.

Douglas, G. W., and **M. Ryan.** 1998. Status of the Montane Yellow Violet, *Viola praemorsa* ssp. *praemorsa* (Violaceae) in Canada. Canadian Field-Naturalist 112: 491–495.

Douglas, G. W., D. B. Straley, and **D. Meidinger.** 1989-91. The vascular plants of British Columbia Parts 1–3. Special Report Series 1–3. Forest Science Research Branch. British Columbia Ministry of Forests. Victoria.

Douglas, G. W., D. B. Straley, and **D. Meidinger.** 1998. The rare native vascular plants of British Columbia. British Columbia Ministry of Environment, Lands, and Parks. Victoria. 423 pages.

Evans, K. 1992. Breeding system of tall bugbane *Cimicifuga elata* (Ranunculaceae). Reed College Biology Department Sandy River Research Report. Portland, Oregon. 26 pages.

Evans, K. 1993. Allozyme variation, population genetic structure, and inbreeding in a rare plant, *Cimicifuga elata* (Ranunculaceae). Reed College Division of Mathematics and Natural Sciences. Portland, Oregon. 45 pages.

Hay, R., and **K. A. Beckett.** 1978. Reader's digest encyclopaedia of garden plants and flowers. The Reader's Digest Association Ltd. London, England. 800 pages.

Hitchcock, C. L., A. Cronquist, M. Ownbey, and **J. W. Thompson.** 1964. Vascular plants of the Pacific Northwest-Part 2: Salicaceae to Saxifragaceae. University of Washington Press. Seattle, Washington. 597 pages.

Jamison, J. A., and **G. W. Douglas.** 1998. Status of Coastal Wood Fern, *Dryopteris arguta* (Dryopteridaceae) in Canada. Canadian Field-Naturalist.112: 284–288.

Kaye, T., and **M. Kirkland.** 1994. *Cimicifuga elata*: Status, habitat analysis, monitoring, inventory, and effects of timber management. Oregon Department of Agriculture – Plant Conservation Biology Program. Eugene, Oregon. 49 pages.

Moore, M. 1993. Medicinal plants of the Pacific West. Red Crane Books. Santa Fe, New Mexico.

Pellmyr, O. 1985a. Pollination adaptations in the Cimicifugae and the evolutionary origin of pollinator-plant mutalism. Acta Universitatis Upsaliensis 2–34.

Pellmyr, O. 1985b. Pollination ecology of *Cimicifuga arizonica* (Ranunculaceae). Botanical Gazette 146: 404–412.

Pellmyr, O. 1986. Pollination ecology of two nectarless *Cimicifuga* sp. (Ranunculaceae) in North America. Nordic Journal of Botany 6: 713–723.

Penny, J. L., G. W. Douglas., and **G. A. Allen.** 1998. Status of Bearded Owl-clover, *Triphysaria versicolor* ssp. *versicolor* (Ranunculaceae), in Canada. Canadian Field Naturalist 112: 481–485.

Shibata, M., M. Ikoma, M. Onada, F. Sato, and **N. Sakuri.** 1980. Pharmacological studies on the crude drug "Shoma:" III. Central depressant and antispasmodic actions of *Cimicifuga rhizoma*, and *Cimicifuga simplex*. Yakugaku Zaahi 100: 1143–1150.

Wentworth, J. 1996. Report on the status in Washington of *Cimicifuga elata* Nutt. Washington Natural Heritage Program. Olympia, Washington. 44 pages.

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Subtidal Fishes Associated with Gravel and Bedrock in the Baie des Chaleurs, Québec

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Twenty-two fish species associated with bedrock and gravel were sampled in the subtidal zone of Port Daniel Bay in the Baie des Chaleurs, Gulf of St. Lawrence. These substrata supported different flora and invertebrates. Although different numbers of fish within species were collected over the two substrata, species diversity measured as species richness and heterogeneity of species, and the number and quantity of prey items in stomach contents were similar. Therefore, a single fish community appeared to occur in the subtidal zone. The logarithmic series described the species heterogeneity, suggesting a mature community. Most fishes preyed on echinoderms, in contrast to studies further south, when the same species primarily preyed on crustaceans.

Key Words: Winter Flounder, *Pleuronectes americanus*, subtidal zone, fish community, Quebec.

A biological community is an assemblage of interacting species within a geographic area that are ecologically dependent on one another (Putman 1994). The subtidal zone is the transitional area between the coastal benthic and pelagic zones, and the intertidal zone. Subtidal fish communities are generally a mixture of fish species from these two zones, and this mixture varies seasonally, annually, and with substratum type (MacDonald et al. 1984).

We sampled the fish associated with gravel and bedrock substrata in Port Daniel Bay, Québec. We used species diversity, number of individuals within each species, and the number and type of prey items in their stomachs to test the hypothesis that the fishes over these two substrata represented a single community. We describe the subtidal fish community of Port Daniel Bay and compare it to those in other regions of Atlantic Canada and New England.

Methods and Materials

We sampled the subtidal fishes of Port Daniel Bay (48°10'00"N; 64°58'00"W) located on the Québec coast of the Baie des Chaleurs, Gulf of St. Lawrence (Figure 1). In this region two unharvested scallop beds (*Placopecten magellanicus*; mean densities >0.30 scallops.m^{-2}; 5 and 3 km^{-2} areas) occur on gravel substratum, divided by a 3 km width bedrock reef (Stokesbury and Himmelman 1993). On the bedrock, the American Lobster (*Homarus americanus*) (mean = 0.19 individuals • m^{-2}, SD = 0.17, in 1991) is the dominant macroinvertebrate (Stokesbury and Himmelman 1995). Both substrata support bryozoans and rhodophytes but significantly greater densities of hydroids are associated with gravel (Stokesbury and Himmelman 1995). Tides in Port Daniel Bay were semidiurnal with a maximum range of 1.7 m during this study. Mean summer water temperature (≅11.1°C, SD = 1.6), salinity (≅29.4 ⁰/oo, SD = 0.9), and current velocities and directions were similar over these two substrata in 1991 and 1992 (Stokesbury and Himmelman 1995). Although many of the fishes and shellfishes inhabiting this region support important sport and commercial fisheries in other areas, fishing effort was low in Port Daniel Bay and primarily directed at lobsters.

From 3 July to 20 September 1991, two 1 × 25 m monofilament trammel nets (250 mm mesh outer walls, 2.5 cm mesh inner wall) were set simultaneously 16 times between 1700 and 0900 h, one on bedrock, and one on gravel in the larger scallop bed near the lighthouse (Figure 1). From 26 June to 5 August 1992, an 8 × 45 m gillnet (7.5 cm mesh) was set on three consecutive nights between 1700 and 0900 h. This gillnet was first set on bedrock, secondly on gravel in the larger scallop bed near the lighthouse and on gravel near Anse à la Barbe on the third evening (Figure 1). Sampling effort was similar, with 16 net sets at each site in 1991 (means of 16.4 hr • set^{-1} per set) and five sets at each site in 1992 (mean of 15.4 hr • set^{-1} per set). All fish collected were identified to species, measured (fork length cm), and their stomach contents were sorted and identified to family. Stomach content wet weights were recorded for the 1992 samples.

Species diversity was measured as species richness and heterogeneity of species. Species heterogeneity compared the number of individuals to

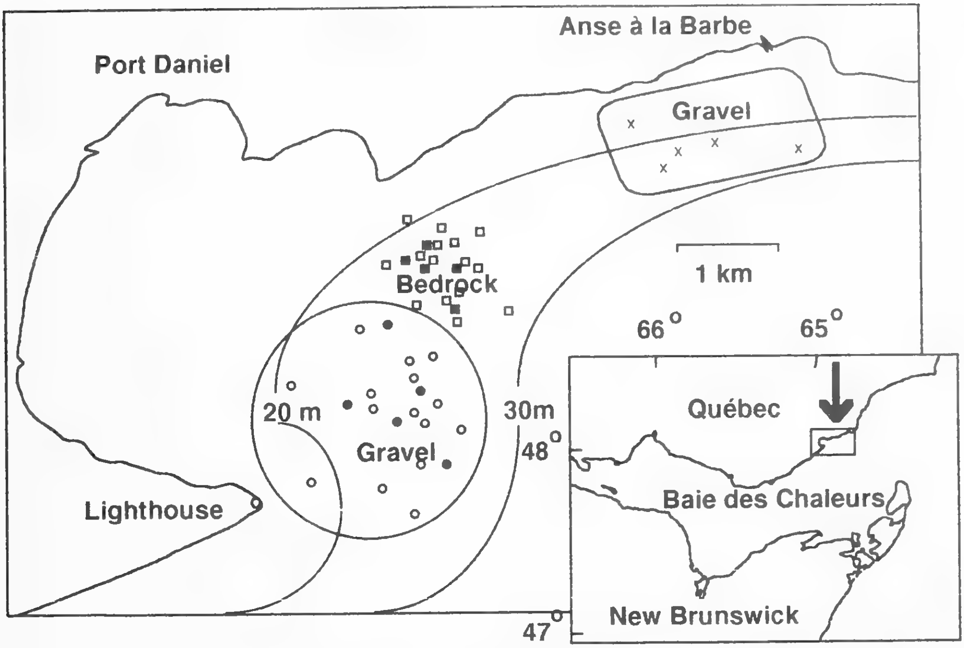

FIGURE 1. Locations of net collections over gravel and bedrock substrata in Port Daniel Bay during 1991 and 1992. Circles and squares represent net collection locations over gravel near the Lighthouse and bedrock, respectively (open equals 1991, shaded equals 1992), net collections over gravel near Anse à la Barbe in 1992 are represented by an x.

ranked abundance. A logarithmic series, calculated with the number of species and the number of individuals, described these data (Krebs 1989). The percent similarity (100% = identical samples) compared the number of species present and their relative proportions between substrata (Krebs 1989). The counts of individuals, species collected and fish lengths were tested for normality and heterogeneity of variance. If the data failed these tests they were transformed using a log (x+1) which corrected for nonnormality and heteroscedasticity before applying statistical tests (Zar 1996). Standard one-way and two-way ANOVAs, and ANCOVAs were used to compare differences in mean values.

Results

Twenty-two fish species were collected in Port Daniel Bay (Table 1). The numbers of species collected over the two substrata were similar. In 1991, the mean numbers of species per net haul were 3.63 (SD = 1.59) and 4.25 (SD = 1.95) collected over gravel-Lighthouse and bedrock, respectively (t-test, df = 31, $t = 0.58$, $p = 0.45$). In 1992, the mean number of species per net haul were 5.20 (SD = 2.8), 5.00 (SD = 0.71), and 4.25 (SD = 1.95) collected over gravel-Lighthouse, -Anse à la Barbe bed, and bedrock, respectively (ANOVA, df = 14, F = 0.52, $p = 0.61$). Logarithmic series indicated that the species heterogeneity over gravel and bedrock were similar (Figure 2).

The species percent similarity comparing the two substrata was 50% in 1991. In 1992, when all three sites were combined, the species percent similarity was 56%. However, percent similarities were higher between any two sites in 1992; gravel-Lighthouse and -Anse à la Barbe (65%), gravel-Lighthouse and bedrock (71%), gravel-Anse à la Barbe and bedrock (73%). In 1991, two of the three most abundant species collected over each substratum were the same while, in 1992, Winter Flounder (*Pleuronectes americanus*) dominated all collections (Table 1).

The number of fish within species collected over bedrock differed significantly from the numbers collected over gravel in 1991 (two-way ANOVA site, species; df = 10, F = 3.70 $p < 0.01$, Table 1). However, the number of fish within species collected over the two substrata were similar in 1992 (two-way ANOVA, site, species; df = 7, F = 0.96 $p = 0.47$, Table 1).

The trammel nets, used during 1991, collected fish with lengths ranging from 12.0 cm to 85.0 cm. The larger meshed gill nets, used during 1992, collected fish with lengths ranging from 21.3 to 73.5 cm. The largest fish collected by both nets was the Atlantic Wolffish (*Anarhichas lupus*). Winter Flounder was the only species collected frequently enough to allow

TABLE 1. Count (n), mean number per net ($\bar{x}$) and standard deviation (SD) of fish collected in Port Daniel Bay during 1991 and 1992.

		1991				1992					
		Gravel (LB)		Bedrock		Gravel (LB)		Gravel (AB)		Bedrock	
Species	Common name	n	$\bar{x}$ (SD)	n	$\bar{x}$ (SD)	n	$\bar{x}$ (SD)	n	$\bar{x}$ (SD)	n	$\bar{x}$ (SD)
Rajiformes											
Raja erinacea	Little Skate	4	0.25 (0.06)	6	0.38 (0.62)	0		2	0.4 (0.89)	1	0.2 (0.45)
Squaliformes											
Squalus acanthias	Spiny Dogfish	0		0		0		2	0.4 (0.89)	0	
Clupeiformes											
Clupea harengus	Atlantic Herring	2	0.13 (0.5)	0		3	0.6 (0.55)	7	1.4 (1.67)	0	
Salmoniformes											
Osmerus mordax	Rainbow Smelt	1	0.06 (0.25)	12	0.75 (1.77)	2	0.4 (0.89)	1	0.2 (0.45)	0	
Gadiformes											
Gadus morhua	Atlantic Cod	4	0.25 (0.45)	3	0.19 (0.4)	8	1.6 (3.58)	1	0.2 (0.45)	2	0.4 (0.89)
Urophycis tenuis	White Hake	5	0.31 (0.48)	4	0.25 (0.58)	2	0.4 (0.89)	8	1.6 (1.14)	1	0.2 (0.45)
Pollachius virens	Pollock	0		2	0.13 (0.5)	0		0		0	
Microgadus tomcod	Atlantic Tomcod	5	0.31 (0.6)	35	2.19 (6.69)	0		0		0	
Scorpaeniformes		2	0.13 (0.5)	2	0.13 (0.34)	0		0		0	
Cycloptterus lumpus	Lumpfish	0		1	0.06 (0.25)	1	0.2(0.45)	1	0.2 (0.45)	0	
Hemitripterus americanus	Sea Raven	0		0		0		1	0.2 (0.45)	4	0.8 (1.1)
Myoxocephalus octodecemspinosus	Longhorn Sculpin	10	0.63 (0.81)	1	0.06 (0.25)	0		0		2	0.4 (0.55)
Myoxocephalus scorpius	Shorthorn Sculpin	14	0.88 (1.14)	19	1.19 (1.56)	9	1.8 (1.92)	2	0.4 (0.55)	5	1 (0.71)
Triglops murrayi	Moustache Sculpin	0		1	0.06 (0.25)	0		0		0	
Sebastes sp.	Sea bass	0		1	0.06 (0.25)	0		0		0	
Perciformes											
Anarhichas lupus	Atlantic Wolffish	0		1	0.06 (0.25)	1	0.2 (0.45)	0		0	
Cryptacanthodes maculatus	Wrymouth	1	0.06 (0.25)	0		0		0		0	
Macrozoarces americanus	Ocean Pout	4	0.25 (0.58)	3	0.19 (0.4)	0		0		0	
Scomber scombrus	Atlantic Mackerel	0		0		1	0.2 (0.45)	4	0.8 (1.79)	1	0.2 (0.45)
Tautogolabrus adspersus	Cunner	20	1.25 (4.74)	107	6.69 (14.7)	0		0		0	
Pleuronectiformes											
Hippoglossoides platessoides	American Plaice	0		0		1	0.2 (0.45)	0		0	
Pleuronectes ferruginea	Yellowtail Flounder	1	0.06 (0.25)	0		3	0.6 (0.89)	1	0.2 (0.45)	1	0.2 (0.45)
Pleuronectes americanus	Winter Flounder	51	3.19 (3.41)	28	1.75 (2.35)	28	5.6 (5.03)	55	11 (11.6)	25	5 (8.49)
Sum		125		226		59		84		42	

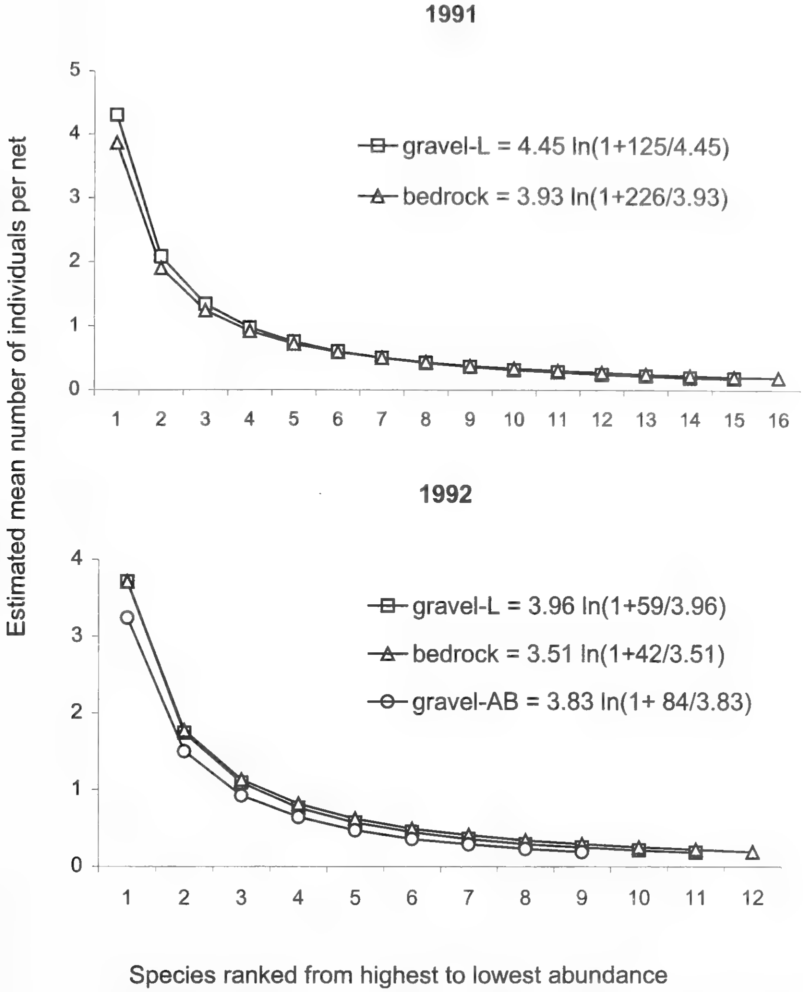

FIGURE 2. Logarithmic series of species abundance over the two substrata in Port Daniel Bay during A) 1991 and B) 1992. (L = area near the Lighthouse, AB = area near Anse à la Barbe).

length comparisons (Figure 3). Lengths of Winter Flounder were similar between locations in 1991 (t-test, df = 63, t = 1.06, p = 0.29) and 1992 (ANOVA, df = 104, F = 2.44, p = 0.09) and during both years (ANOVA, df = 169, F = 1.5, p = 0.20).

Most fish preyed on invertebrates, 81 and 74 % over gravel and bedrock, respectively, in 1991, and 74, 67, and 74 % over gravel-Lighthouse, bedrock and gravel-Anse à la Barbe, respectively, in 1992. Echinoderms were the primary prey. Atlantic Cod (*Gadus morhua*), Rainbow Smelt (*Osmerus mordax*), White Hake (*Urophycis tenuis*), Winter Flounder, Shorthorn Sculpin (*Myoxocephalus scorpius*), and Little Skate (*Raja erinacea*) preyed on fish and invertebrates. No fish were exclusively piscivorous. In 1991, 41.1 and 41.8 % of the fish examined had empty stomachs in the gravel-lighthouse and bedrock sites, respectively. The percentage of fish with empty stomachs decreased to between 23.8 and 30.2% for the three locations in 1992.

Winter Flounder was the only species collected frequently enough to allow comparison of stomach contents. Echinoderms (mostly Ophiuroidea) were the Winter Flounder's primarily prey followed by mollusks and polychaetes. The mean wet weight of stomach contents of Winter Flounder were also similar (mean = 2.7 g SD = 2.6, mean = 3.1 g SD = 3.5, and mean = 2.1 g SD = 2.3, over the gravel-Lighthouse, bedrock, and gravel-Anse à la Barbe, respectively; ANCOVA covariate = length; df = 2, 1, 2, 79; F = 2.44; p = 0.09).

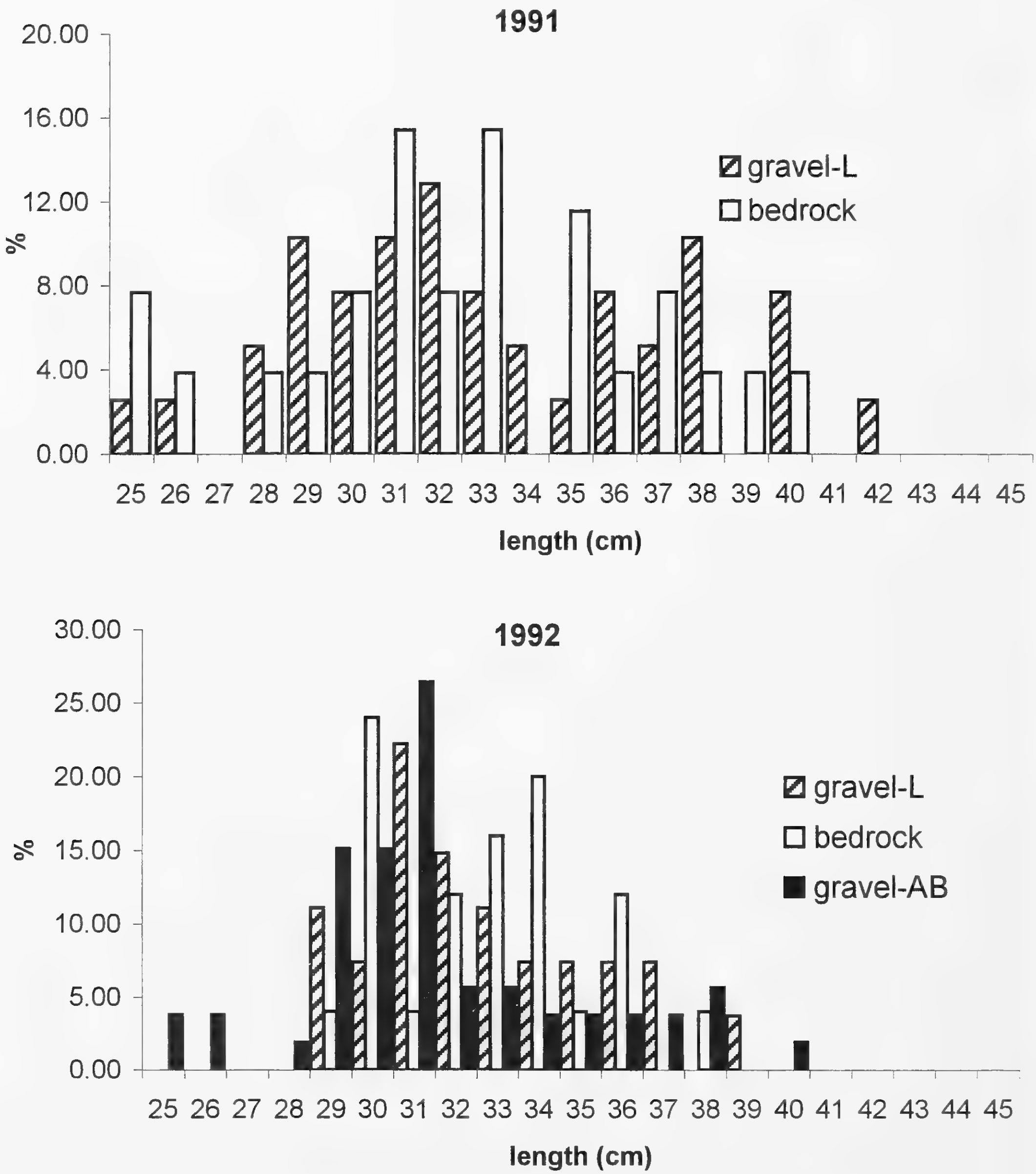

FIGURE 3. Precent length frequency (cm) of the Winter Flounder (*Pleuronectes americanus*), collected in Port Daniel Bay over gravel and bedrock substrates during the summer months of 1991 and 1992. (L = area near the Lighthouse, AB = area near Anse à la Barbe).

Discussion

A single fish community appears to occur in the subtidal zone of Port Daniel Bay over both gravel and bedrock. The logarithmic series suggests a mature community structure (Krebs 1989; Putman 1994). The single characteristic suggesting that the fish assemblages collected over each substratum differed was the number of individuals within each species. However, two of the three most abundant species collected over each substratum were the same in 1991 while Winter Flounder dominated collections in 1992.

Gill and trammel nets are highly size selective and provide only a relative sample of the fish community. With a wider range of gear, sampling a greater variety of sizes and spatial scales, it may be possible to determine differences that were unobserved during this study.

The subtidal fishes collected in Port Daniel Bay were similar to those sampled in other regions of Atlantic Canada and New England. The same species were collected in the inter- and subtidal zones (18 species) along the southern Atlantic coast of Nova Scotia and in Passamaquoddy Bay (62 species) along the Bay of Fundy, New Brunswick (Tyler 1971; Black and Miller 1991). The similarity in species composition decreased as the study sites were located further south. Of the 23 species collected in the lower Mystic River, Massachusetts, 10 species were the same as those collected in Port Daniel Bay (Haedrich and Haedrich 1974). Of the 41 listed species sampled in Narragansett Bay, Rhode Island, only 11 were also collected in Port Daniel Bay (Oviatt and Nixon 1973). Tyler (1971) also observed this pattern. However, in all these studies Winter Flounder dominated the subtidal ichthyofauna, with two exceptions, Cunner (*Tautogolabrus adspersus*) dominated the bedrock site in Port Daniel Bay in 1991 and in the rocky intertidal zone in south-western Nova Scotia (Black and Miller 1991). Within its distribution, densities of Winter Flounder vary seasonally in response to changes in water temperature (Haedrich and Haedrich 1974; MacDonald et al. 1984). The occurrence and distribution of adult benthic fishes in the North Atlantic is usually related to substrate type and temperature, with marked seasonal variations (for a review see MacDonald et al. 1984).

Fishes collected in Port Daniels Bay were omnivorous preying on invertebrates, primarily echinoderms; for example, Winter Flounder preyed on echinoderms, mollusks, and polychaetes over both substrata. Small crustaceans and small gastropods are the primary food of both mobile and sedentary fishes in southwestern Nova Scotia (Black and Miller 1991). Epifauna are much more important prey than infauna, plankton or other fish in Long Island Sound (Richards 1963). Crustaceans are the primary prey of demersal fish in Narragansett Bay, except for Winter Flounder which prey primarily on mollusks (Oviatt and Nixon 1973).

A large number of fish of all species had empty stomachs in 1991 and 1992 in Port Daniel Bay. We sampled during the summer, when feeding was intense and during the night when most fish were foraging for prey. Although some fish may have been collected before they had a chance to feed, the percentage of empty stomachs still seems high. Only 2 to 17 % of the Winter Flounder collected with similar trammel nets set for 2 hours in the inter and subtidal zones of south-western Nova Scotia had empty stomachs (Black and Miller 1991). Perhaps this difference in stomach fullness is related to the shift from crustaceans to echinoderms and the densities of these primary prey as sample locations move from southern to northern latitudes.

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Literature Cited

Black, R., and **R. J. Miller.** 1991. Use of the intertidal zone by fish in Nova Scotia. Environmental Biology of Fishes 31: 109–121.

Haedrich, R. L., and **S. O. Haedrich.** 1974. A seasonal survey of the fishes in the Mystic river, a polluted estuary in downtown Boston, Massachusetts. Estuarine and Coastal Marine Science 2: 59–73.

Krebs, C. J. 1989. Ecological Methodology. Harper & Row, Publishers, Inc., New York.

MacDonald, J. S., M. J. Dadswell, R. G. Appy, G. D. Melvin, and **D. A. Methven.** 1984. Fishes, fish assemblages, and their seasonal movements in the lower Bay of Fundy and Passamaquoddy Bay, Canada. Fisheries Bulletin 82: 121–139.

Oviatt, C. A., and **S. W. Nixon.** 1973. The demersal fish of Narragansett bay: an analysis of community structure, distribution and abundance. Estuarine and Coastal Marine Science 1: 361–378.

Putman, R. J. 1994. Community Ecology. Chapman & Hall, London.

Richards, S. W. 1963. The demersal fish population of Long Island Sound. Bulletin of the Bingham Oceanographic Collection 18: 5–101.

Stokesbury, K. D. E., and **J. H. Himmelman.** 1993. Spatial distribution of the giant scallop *Placopecten magellanicus* in unharvested beds in the Baie des Chaleurs, Québec. Marine Ecology Progress Series 96: 159–168.

Stokesbury, K. D. E., and **J. H. Himmelman.** 1995. Biological and physical variables associated with aggregations of the giant scallop *Placopecten magellanicus*. Canadian Journal of Fisheries and Aquatic Sciences 52: 743–753.

Tyler, A. V. 1971. Periodic and resident components in communities of Atlantic fishes. Journal of the Fisheries Research Board of Canada 28: 935–946.

Zar, J. H. 1996. Biostatistical analysis. Prentice Hall, New Jersey.

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Recovery of a Cliff-nesting Peregrine Falcon, *Falco peregrinus*, Population in Northern New York and New England, 1984–1996

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Following extirpation by DDT in the 1960s, a cliff-nesting population of Peregrine Falcons was reestablished in northern New York and New England. In 1984-1996, occupied territories grew at an annual rate of 16% with average productivity of 1.29 fledglings/territorial pair and nest success of 73%. Geographical variability in reproductive success was prevalent within the region. Lower reproductive performance in the White Mountain subpopulation in particular, was not related to density dependent or weather factors, but was significantly correlated to a lower percentage of doves (Rock + Mourning) in the diet. In addition to providing a large amount of biomass per unit catch effort, low trophic-level granivorous doves accumulate lower contaminant levels than insectivorous prey species. Because doves are primarily associated with agricultural habitats, geographic variability in reproductive performance within this region may ultimately be related to habitat differences.

Key Words: Peregrine Falcon, *Falco peregrinus*, DDT, diet, northern New York and New England, population monitoring, weather effects

A minimum of 350 pairs of Peregrine Falcons (*Falco peregrinus*) nested east of the Rocky Mountains (Hickey 1942) prior to the widespread use of DDT (*ca.* 1945), but by the mid-1960s, peregrines were completely extirpated from eastern North America (Berger et al. 1969; Fyfe et al. 1976). The role of DDT's metabolite, DDE, as a major causal factor in this decline has been well documented (Ratcliffe 1967; Peakall 1976; Peakall 1993). The banning of DDT use in 1972, the active role of many private organizations (e.g., The Peregrine Fund, Inc.) and implementation of a recovery plan (USFWS 1991, revised) helped to successfully reestablish this species (Enderson et al. 1995) in its former niche in the Adirondack and Appalachian mountains of the northeastern U.S. The recovery plan established five regions (mid-Atlantic Coast, northern New York and New England [NNYNE], southern Appalachians, Great Lakes, and southern New England/central Appalachians) in the historical range of the eastern subspecies *F. p. anatum*, and more than 850 young falcons were released from 1974–1996 in NNYNE and adjacent Canadian provinces (USFWS 1991; C. S. Todd, Maine Department of Inland Fisheries and Wildlife, unpublished data).

Historically, eastern peregrines nested nearly exclusively on cliffs (Hickey 1942), and in 1981 a historical nesting cliff in Franconia, New Hampshire, became the first confirmed reoccupied breeding territory in NNYNE. By 1996, the population had grown to 42 cliff-nesting pairs, or about 50% of the estimated historical population (Hickey 1942). In contrast, about 85% of peregrines in the other eastern recovery regions nest on human-made structures (Cade and Bird 1990; Cade et al. 1996). In this paper we report on the return of Peregrine Falcons to a large portion of their ancestral eastern cliff-nesting habitat, and we examine whether two factors known to affect peregrine reproductive success, weather and diet, could explain the significant geographical variation in productivity we observed within NNYNE.

Study Area and Methods

In order to analyze geographic trends in productivity, we divided NNYNE into six ecoregions (Figure 1) based on ECOMAP ecosystems (USDA 1993). The units differed from each other with respect to soil type, elevation, precipitation, temperature, growing season, disturbance regimes, and land use. The Champlain is the most heavily cleared for agriculture (75%), whereas the montane ecoregions are between 80–90% forested. The White Mountain ecoregion has the highest peaks in the northeast, has the shortest growing season, and the highest percentage of forest cover (USDA 1993).

Beginning in the mid-1980s nesting activity and breeding success were monitored (Audubon Society

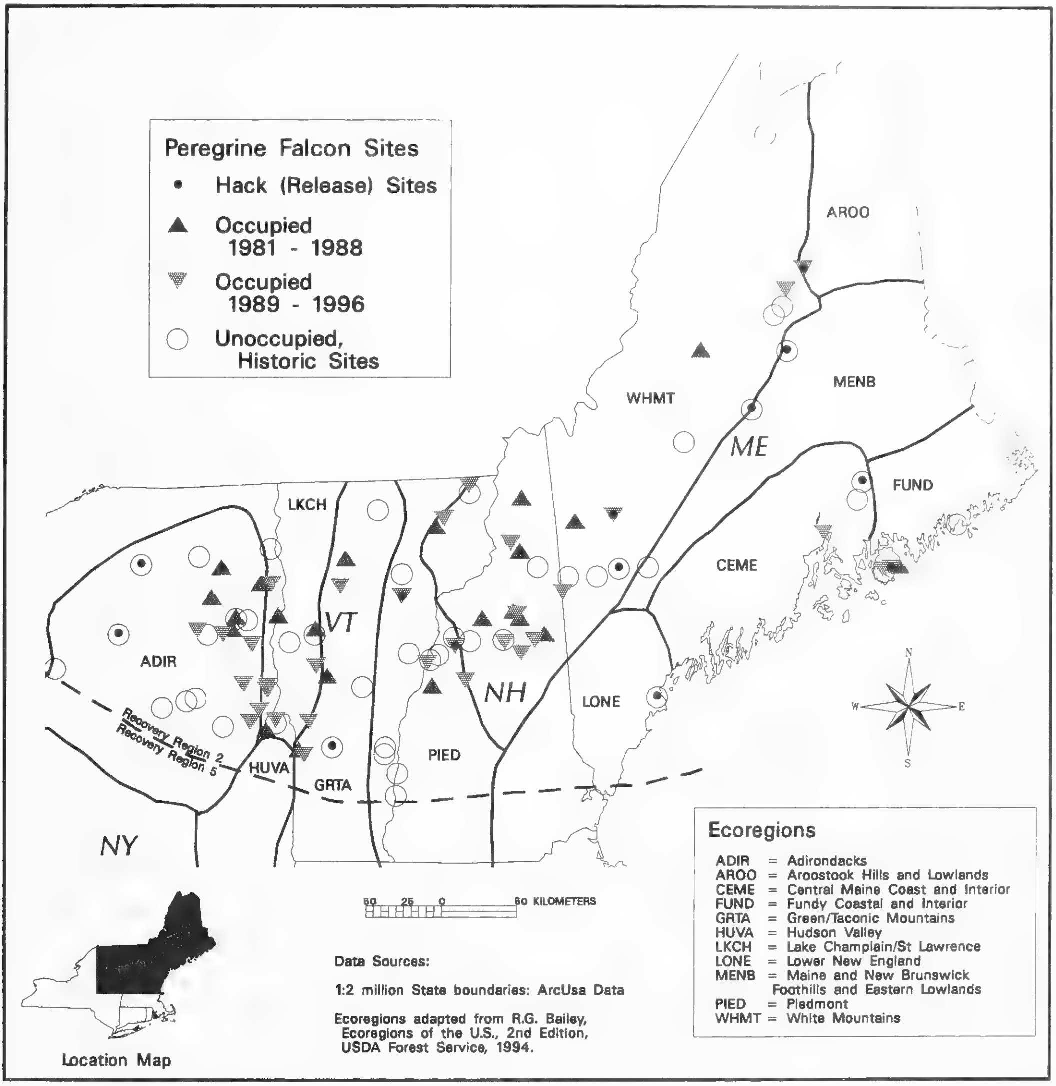

FIGURE 1. Ecoregions, location and reoccupancy chronologies of 42 Peregrine Falcon nest sites in northern New York and New England. Open circles mark unoccupied cliffs, or an unoccupied hack site.

of New Hampshire; Maine Department of Inland Fisheries and Wildlife; New York State Department of Environmental Conservation; Vermont Institute of Natural Science, all unpublished data) as stipulated by the Eastern Peregrine Falcon Recovery Plan (USFWS 1991, revised). Active sites (a pair of falcons at a potential nest cliff) were monitored weekly (April–July) using standard methods outlined by Cade et al. (1996). Successful nests fledged ≥ 1 young, and only wild-fledged young were counted in productivity rates (young fledged/territorial pair). Observer bias (Hickey 1969; Grier and Barclay 1988) may be important as many different observers monitored cliffs.

Peregrine diets in the Champlain, Green/Taconic Mountains, Piedmont, and White Mountain ecoregions were determined from prey remains collected in late May–June at 19 different successful eyries in New Hampshire and Vermont in 1989–1996. Prey remains recovered from nests were identified by T. French (Massachusetts Division of Fish and Wildlife) by comparing pellets, feathers, mandibles, feet, wings, and other anatomical parts to museum specimens (Sabo and Laybourne 1994). Percent biomass of prey in the diet was calculated as the number of individuals of a taxon × the estimated average weight (Dunning 1984) of that species/ total biomass of all species.

Annual nest site observations (n = 331), mean monthly temperature and precipitation totals from weather stations nearest each cliff (New England Climate 1984–1996; New York State Climate 1984–1996), and individual prey items served as units statistical analyses. We used ANOVA to compare ecoregional and weather effects on productivity and nest success. Pairs of means after ANOVA were analyzed with Least Significant Difference (LSD) tests. We incorporated cliff area (length × height of the exposed rock face estimated by W. R. Spofford [unpublished data]) into a least-squares multiple regression model to test whether nest success was influenced by May precipitation at different-sized cliffs. Nested, least-squares ANOVA models and added variable (residual) plots were used for analysis of peregrine diets. All statistical tests were performed on JMP (SAS Institute 1995) at the $P = 0.05$ level of significance.

Results

The number of territorial falcon pairs and young fledged in NNYNE increased rapidly from 1984 through 1996 (Table 1; Figure 2). Occupied territories increased at an annual rate (r) of 16% over the 13-year period, but r = 6.7% after 1990, possibly reflecting the virtual cessation of hacking (only Maine hacked after 1987). Density dependence was not detected regionwide, nor within any one ecoregion, when productivity was regressed on the number of pairs (slope ≤ 0.03; $P > 0.19$). Despite nearly two-fold annual variability in productivity and nest success (Table 1), differences were not significant ($P > 0.15$), so we combined years for the ecoregional analysis.

Long-term mean productivity ranged from 1.12 in the White Mountain ecoregion to 1.81 in the Piedmont (Table 2; Figure 3). Productivity was significantly ($P < 0.05$) lower in the White Mountains than in the Champlain and Piedmont ecoregions and was characterized by a relatively high incidence of nest failure (Table 2; Figure 3). The nest success rate of 59% in the White Mountains was significantly lower ($P < 0.0001$) than in the Adirondack and Champlain ecoregions.

The amount of precipitation in May varied annually ($P < 0.0001$) and among ecoregions ($P < 0.0002$). Nevertheless, neither total precipitation, nor departures from long-term means, were significantly correlated with productivity ($P > 0.13$) or nest success ($P > 0.26$) regionwide, or within any ecoregion ($P > 0.13$), even with cliff area in the regression model ($P > 0.5$) . Similarly, we found no correlations ($P > 0.05$) of April precipitation, Spring temperature, or winter (December, January, February) weather effects on peregrine reproductive performance in NNYNE.

Composition of peregrine diets was significantly ($P < 0.0001$) different among the ecoregions (Figure 4). In both the Champlain and Green/Taconic ecoregions nearly 75% of prey biomass consisted of doves (*Columba livia, Zenaida macroura*), whereas in the White Mountain ecoregion these species accounted for only 42% of prey biomass. Passerines formed higher percentages of the White Mountain diet (Figure 4). With the effects of average prey biomass removed using residual plots (Figure 5), nest success was highly significantly ($r^2 = 0.98$; $P < 0.0001$) correlated to a diet consisting of Doves

TABLE 1. The number of territorial pairs, fledglings, nest success, and productivity of reestablished Peregrine Falcons in northern New York and New England, 1984–1996 (Audubon Society of New Hampshire, Maine Department of Inland Fisheries and Wildlife, New York State Department of Environmental Conservation, Vermont Institute of Natural Science, unpublishyed data).

	Pairs			Fledglings		
	Territorial	Successful	Success(%)	Number	Number/ successful pair	Number/ territorial pair
1984	5	0	0	0	0	0
1985	9	5	83	13	2.6	1.44
1986	9	8	100	16	2.0	1.78
1987	17	7	58	16	2.14	0.88
1988	21	12	75	22	1.83	1.05
1989	26	16	76	32	2.0	1.23
1990	29	13	57	29	2.23	1.0
1991	28	18	69	42	2.33	1.50
1992	35	19	68	38	2.0	1.09
1993	34	26	84	54	2.08	1.59
1994	37	26	79	58	2.23	1.57
1995	39	31	82	61	1.97	1.56
1996	42	21	64	48	2.29	1.14
1984–1996	331	202	73	428	2.12	1.29

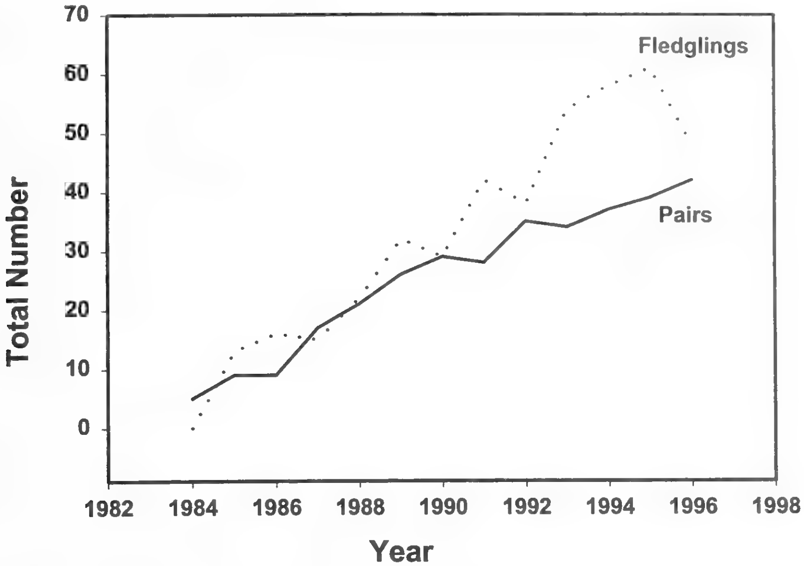

FIGURE 2. Peregrine Falcon reproductive trends in northern New York and New England. Overall mean annual growth (r) in territorial pairs for the period was 16%.

at 11 eyries where peregrines nested for at least four years, and prey remains were collected in two different years.

Discussion

Reproductive performance often varies geographically in peregrine populations (Ratcliffe 1993), and the reproductive rate (fledglings/territorial pair) frequently is used as a measure of relative population health (Peakall and Kiff 1988; Ratcliffe 1993). Given reasonable mortality estimates, a reproductive rate between 1.25–1.50 generally produces positive population growth rates (Grier and Barclay 1988; Wootton and Bell 1992) and indicates that DDE has not caused excessive reproductive failure (Hickey and Anderson 1969; Mearns and Newton 1984; Ratcliffe 1993). In addition to DDE contamination, falcon reproductive performance may be affected by factors such as age and experience of breeders (Newton and Rothery 1997), density (Newton 1979), availability of nest sites (Hunt 1988), prey availability (Thiollay 1988), adverse weather events (Squires et al. 1991), and combinations of these factors.

For example, adverse weather during advanced incubation and early hatchling stages (May in NNYNE) has been demonstrated to lower peregrine reproductive success by hampering the foraging success of adult birds, and/or biophysically stressing vulnerable young chicks (Ratcliffe 1984; 1988; 1993). Newton and Mearns (1988) found a negative correlation between nesting success and the amount of precipitation in May in Scotland, and Norriss (1995) also correlated productivity with spring rainfall in Ireland, showing elevated effects at smaller,

TABLE 2. Ecoregional productivity and nesting success of Peregrine Falcons in northern New York and New England, 1984–1996 (Data sources as in Table 1).

	Productivity			Nesting success		
Ecoregion	Pairs	Fledglings/ territorial pair	SE	Nest attempts	Success (%)	SE
Adirondack	59	1.19	0.16	47	91[2]	0.06
Champlain	50	1.59[1]	0.18	41	93[2]	0.06
Green/Taconic	46	1.30	0.18	35	77	0.07
Maine Coast	14	1.50	0.33	9	78	0.14
Piedmont	21	1.81	0.27	19	79	0.10
White Mountains	142	1.12[1]	0.10	125	59	0.04

[1]White Mountains significantly different ($P < 0.05$) from both Champlain and Piedmont.
[2]White Mountains significantly different ($P < 0.0001$) from both Champlain and Piedmont.

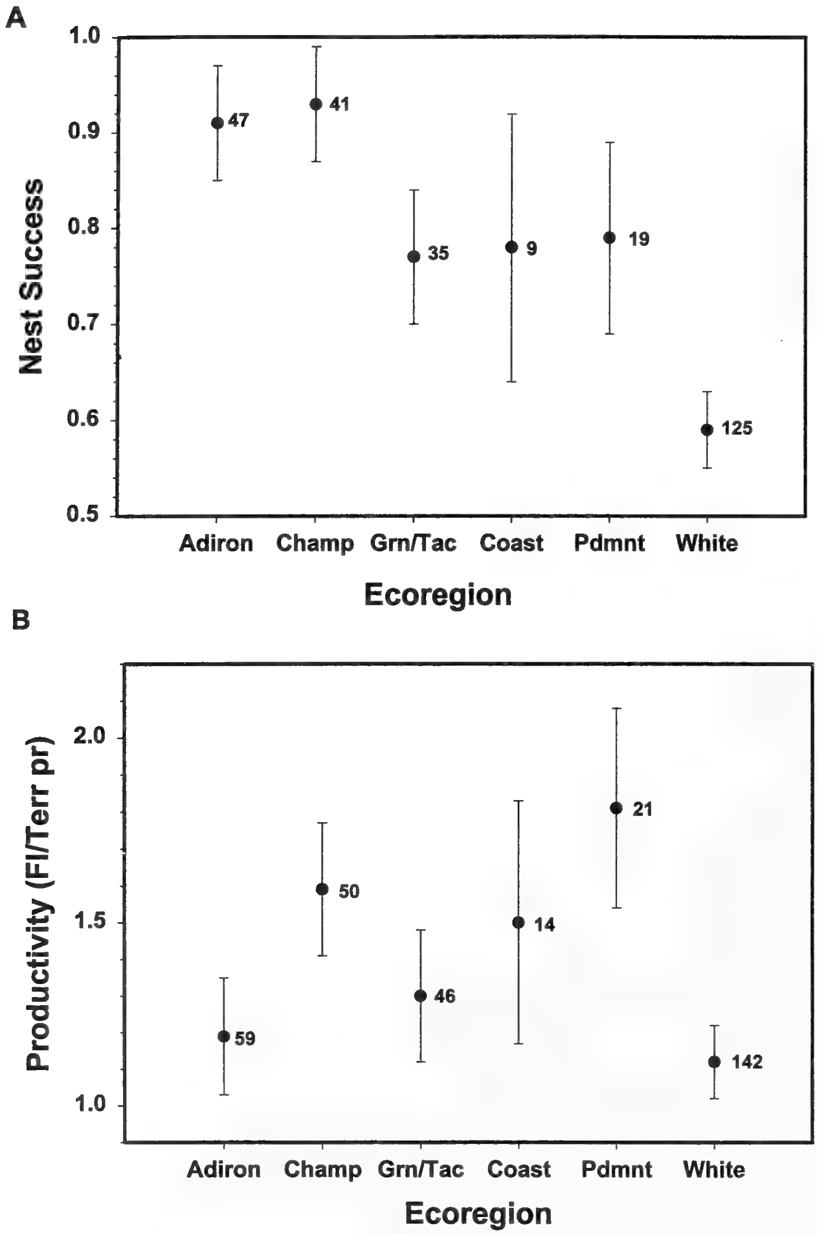

FIGURE 3. Nest success (A) and productivity (B) of Peregrine Falcons in six ecoregions in northern New York and New England, 1984–1996. Bars are ± S.E. Numbers next to means are nest attempts (A) and territorial pairs (B). Abbreviations: Adiron, Adirondack Mountains; Cham, Champlain Valley; Grn/Tac, Green/Taconic Mountains; Pdmnt, Piedmont; White, White Mountains.

presumably less-sheltered, cliffs. Owing to biomagnification, peregrines feeding at higher (e.g., insectivorous) and/or aquatic trophic levels have elevated contaminant loads (Lindberg et al. 1985; Baril et al. 1990; Fyfe et al. 1990; Johnstone et al. 1996) which can diminish reproductive performance (Enderson et al. 1982; Peakall and Kiff 1988; Court et al. 1990; Banasch et al. 1992).

The mean productivity rate of 1.29 (Table 1) in NNYNE in 1984–1996 is comparable to pre-DDT

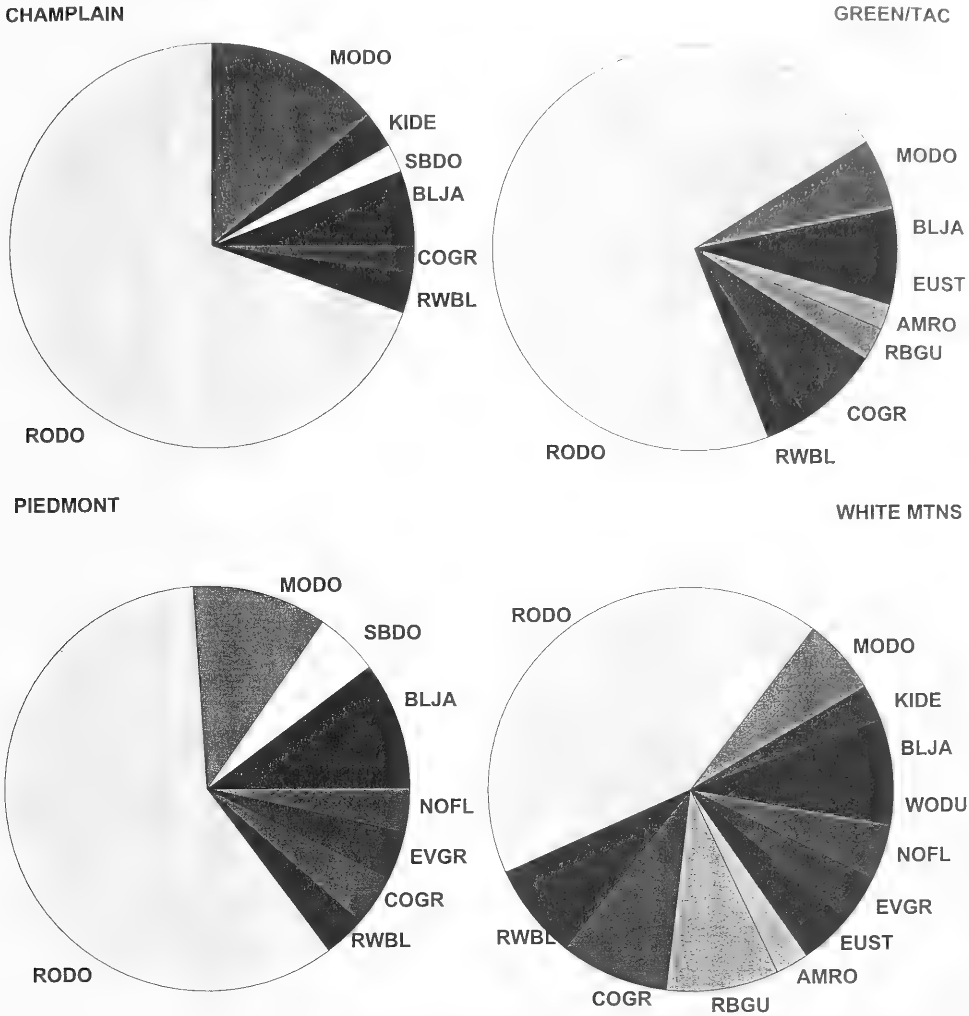

FIGURE 4. Relative biomass (%) of avian prey items comprising ≥2% of total biomass recovered from Peregrine Falcon nests in the Champlain (1 eyrie, n = 6), Green/Taconic (4 eyries, n = 13), Piedmont (3 eyries, n = 8) and White Mountain (11 eyries, n = 24) ecoregions in northern New York and New England, 1989–1996. The overall sample (n = 51) included a minimum of 480 individuals from 50 different taxa at 19 eyries for a total biomass of 70.3 kg. Abbreviations: AMRO, American Robin, *Turdus migratorius*; BLJA, Blue Jay, *Cyanocitta cristata;* COGR, Common Grackle, *Quiscalus quiscula;* EUST, European Starling, *Sturnus vulgaris*; EVGR, Evening Grosbeak, *Coccothrautes vespertinus*; KIDE, Killdeer, *Charadrius vociferus*; MODO, Mourning Dove, *Zenaida macroura*; NOFL, Northern Flicker, *Colaptes auratus*; RWBL, Red-winged Blackbird, *Agelaius phoeniceus*; RBGU, Ring-billed Gull, *Larus delawarensis*; RODO, Rock Dove, *Columba livia*; SBDO, Short-billed Dowitcher, *Limnodromus griseus*; WODU, Wood Duck, *Aix sponsa*.

productivity in the northeastern U.S (Hickey 1942; Hagar 1969; Herbert and Herbert 1969), and should allow for continued population growth, especially because density dependence was lacking, and many historically-occupied cliffs were vacant (Faccio and Corser 1995). An earlier investigation of a reestablished peregrine population in the mid-Atlantic recovery region (Steidl et al. 1991) found slightly higher productivity (1.38) but lower nest success (62%) rates.

Given the large size of the White Mountain ecoregion (Figure 1) and the abundant cliff habitat there, it is notable that peregrine reproductive performance was significantly lower than in some other NNYNE ecoregions (Table 2; Figure 3). Our analyses indicated that this was not related to density dependent or

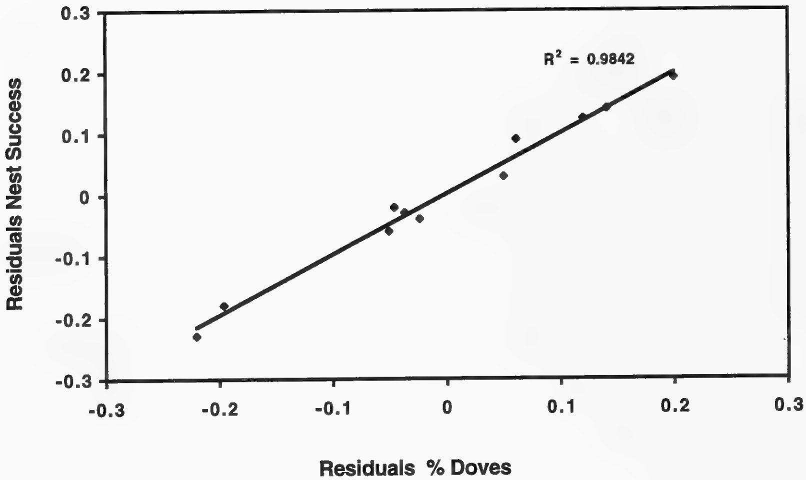

FIGURE 5. Least-squares linear regression of nest success rate on percentage of doves at 11 NNYNE eyries where ≥two prey samples were collected and peregrines nested for ≥ four years in Northern New York and New England, 1989–1996. Residual plot removes confounding effects of average prey biomass (total prey biomass/number of samples) showing a strong significant ($r^2 = 0.98$; $P < 0.0001$) relationship between nest success and the prevalence of doves in the diet.

weather effects, but instead may be due to the peregrines' reliance on smaller omnivorous prey species such as Common Grackles (*Quiscalus quiscula*), Blue Jays (*Cyanocitta cristata*), and Red-winged Blackbirds (*Agelaius phoeniceus*), as opposed to granivorous doves which made up ≥2/3 of prey biomass in the other ecoregions (Figure 4).

Historically, doves were an important prey item for northeastern peregrines (Hickey and Anderson 1969) and, as granivores, they generally accumulate much lower contaminant levels than smaller omnivorous passerines (Enderson et al. 1982), while presumably providing more biomass per unit catch effort. Because we did not measure contaminant levels in peregrines or their prey, it is unclear whether differences in reproductive performance result from a largely passerine diet with higher contaminant concentrations. Nevertheless, doves clearly play a prominent role in the reproductive performance of NNYNE peregrines.

Chronic nest failure at some White Mountain eyries (Audubon Society of New Hampshire, unpublished data; Maine Department of Inland Fisheries and Wildlife, unpublished data), high rates of eggshell thinning (Gilroy and Barclay 1988; USFWS unpublished data), prolonged incubation periods (Martin and North 1993) and high PCB and organochlorine levels in unhatched eggs (Burns et al. 1994; Jarman et al. 1993) all suggest that peregrines in this area may be experiencing ongoing exposure to high levels of contamination. Because doves tend to thrive in agricultural and non-forested (DeGraaf and Rudis 1987) such as the Champlain and Piedmont ecoregions, geographic variability in peregrine reproductive performance may ultimately be related to habitat differences.

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Literature Cited

Banasch, U., J. P. Goossen, A. Einstein Riez, C. Casler, and **R. D. Barradas.** 1992. Organochlorine contaminants in migrant and resident prey of Peregrine Falcons, *Falco peregrinus*, in Panama, Venezuela, and Mexico. Canadian Field-Naturalist 106: 493–498.

Baril, A., J. E. Elliott, J. D. Somers, and **G. Erickson.** 1990. Residue levels of environmental contaminants in prey species of the Peregrine Falcon, *Falco peregrinus*, in Canada. Canadian Field-Naturalist 104: 273–284.

Berger, D. D., C. R. Sindelar, and **K. E. Gamble.** 1969. The status of the breeding peregrines of the eastern

United States. Pages 165–173 *in* Peregrine falcon populations: their biology and decline. *Edited by* J. J. Hickey. University Wisconsin Press, Madison.

Burns, S. A., W. M. Jarman, T. J. Cade, L. F. Kiff, and **B. J. Walton.** 1994. Organochlorines and eggshell thinning in peregrine falcon, *Falco peregrinus*, eggs from the eastern United States, 1986–1988. Pages 709–716 *in* Raptor Conservation Today. *Edited by* B. U. Meyburg and R. D. Chancellor. The Pica Press.

Cade, T. J., and **D. M. Bird.** 1990. Peregrine falcons (*Falco peregrinus*) nesting in an urban environment: a review. Canadian Field-Naturalist 104: 209–218.

Cade, T. J., J. H. Enderson, and **J. Linthicum.** 1996. Guide to management of peregrine falcons at the eyrie. The Peregrine Fund, Inc., Boise.

Court, G. S., C. C. Gates, D. A. Boag, J. D. MacNeil, D. M. Bradley, A. C. Fesser, J. R. Patterson, G. B. Stenhouse, and **L. W. Oliphant.** 1990. A toxicological assessment of peregrine falcons, *Falco peregrinus tundrius*, breeding in the Keewatin district of the Northwest Territories, Canada. Canadian Field-Naturalist 104: 255–272.

DeGraaf, R., and **D. E. Rudis.** 1987. Northeastern wildlife: habitat, natural history, and distribution. U.S. Department of Agriculture, Northeast Forest Experiment Station. General Technical Report NE-18.

Dunning, J. B. 1984. Body weights of 686 species of North American birds. Western Bird Banding Association. Monograph 1. 38 pages.

Enderson, J. H., G. R. Craig, W. A. Burnham, and **D. D. Berger.** 1982. Eggshell thinning and organochlorine residues in Rocky Mountain peregrines (*Falco peregrinus*) and their prey. Canadian Field–Naturalist 96: 255–264.

Enderson, J. H., W. Heinrich, L. Kiff, and **C. M. White.** 1995. Population changes in North American peregrines. Transactions of the North American Wildlife and Natural Resources Conference 60: 142–161.

Faccio, S. D., and **J. D. Corser.** 1995. The reoccupancy of historic Peregrine Falcon nest sites in Vermont: their current status, and future prospects. Vermont Botanical and Bird Club, Joint Bulletin Number 21.

Fyfe, R. W., S. A. Temple, and **T. J. Cade.** 1976. The 1975 North American peregrine falcon survey. Canadian Field–Naturalist 90: 228–273.

Fyfe, R.W., U. Banasch, V. Benavides, N. Hilgert deBenavides, A. Luscombe, and **J. Sanchez.** 1990. Organochlorine residues in potential prey of Peregrine Falcons, *Falco peregrinus*, in Latin America. Canadian Field-Naturalist 104: 285–292.

Gilroy, M. J., and **J. H. Barclay.** 1988. DDE residues and eggshell characteristics of reestablished peregrines in the eastern United States. Pages 403–411 *in* Peregrine falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund Inc., Boise.

Grier, J. W., and **J. H. Barclay.** 1988. Dynamics of founder populations established by reintroduction. Pages 689–700 *in* Peregrine falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund Inc., Boise.

Hagar, J. A. 1969. History of the Massachusetts peregrine falcon population, 1935–1957. Pages 123–131 *in* Peregrine falcon populations: their biology and decline. *Edited by* J. J. Hickey. University of Wisconsin Press, Madison.

Herbert, R. A., and **K. G. S. Herbert.** 1969. The extirpation of the Hudson River peregrine falcon population. Pages 133–154 *in* Peregrine falcon populations: their biology and decline. *Edited by* J. J. Hickey. University of Wisconsin Press, Madison.

Hickey, J. J. 1942. Eastern population of the duck hawk. Auk 59: 176–204.

Hickey, J. J., and **D. W. Anderson.** 1969. The peregrine falcon: life history and population literature. Pages 3–42 *in* Peregrine falcon populations: their biology and decline. *Edited by* J. J. Hickey. University of Wisconsin Press, Madison.

Hickey, J. J. 1969. Peregrine Falcon populations: their biology and decline. University of Wisconsin Press, Madison.

Hunt, W. G. 1988. The natural regulation of peregrine falcon populations. Pages 667–676 *in* Peregrine falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund Inc., Boise.

Jarman, W. M., R. J. Norstrom, M. Simon, S. A. Burns, C. A. Bacon, and **B. R. T. Simoneit.** 1993. Organochlorines, including Chlordane compounds and their metabolites, in Peregrine Falcon, Prairie Falcon, and Clapper Rail eggs from the USA. Environmental Pollution 81: 127–136.

Johnstone, R. M., G. S. Court, A. C. Fesser, D. M. Bradley, L. W. Oliphant, and **J. D. MacNeil.** 1996. Long–term trends and sources of organochlorine contamination in Canadian Tundra Peregrine Falcons, *Falco peregrinus tundrius*. Environmental Pollution 93: 109–120.

Lindberg, P., T. Odsjo, and **L. Reutergardh.** 1985. Residue levels of Polychlorobiphenyls, DDT's, and Mercury in bird species commonly preyed upon by the Peregrine Falcon in Sweden. Archives of Environmental Contamination and Toxicology 14: 203–212.

Martin, C. J., and **D. J. North.** 1993. Peregrine falcons incubate clutch of eggs for minimum of 73 days. Journal of Raptor Research 27: 173.

Mearns, R., and **I. Newton.** 1984. Turnover and dispersal in a peregrine (*Falco peregrinus*) population. Ibis 126: 347–355.

New England Climate. 1984–1996. Northeast Climate Center, May. Cornell University, Ithaca, New York.

New York State Climate. 1984–1996. Northeast Climate Center, May. Cornell University, Ithaca.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota.

Newton, I., and **R. Mearns.** 1988. Population ecology of peregrines in south Scotland. Pages 651–665 *in* Peregrine falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C.White. The Peregrine Fund Inc., Boise.

Newton, I., and **P. Rothery.** 1997. Senescence and reproductive value in sparrowhawks. Ecology 78: 1000–1008.

Norriss, D. W. 1995. The 1991 survey and weather impacts on the peregrine (*Falco peregrinus*) breeding population in the Republic of Ireland. Bird Study 42: 20–30.

Peakall, D. B. 1976. The Peregrine Falcon and pesticides. Canadian Field-Naturalist 90: 301–307.

Peakall, D. B., and **L. F. Kiff.** 1988. DDE contamination in peregrines and American Kestrels and its effect on reproduction. Pages 337–350 *in* Peregrine Falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund Inc., Boise.

Peakall, D. B. 1993. DDE-induced eggshell thinning: an environmental detective story. Environmental Reviews 1: 13–20.

Ratcliffe, D. A. 1967. Decrease in eggshell weight of certain birds of prey. Nature 215: 208–210.

Ratcliffe, D. A. 1984. The peregrine breeding population of the United Kingdom in 1981. Bird Study 31: 1–18.

Ratcliffe, D. A. 1988. The Peregrine Falcon population of Great Britain and Ireland, 1965–85. Pages 147–157 *in* Peregrine Falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund Inc., Boise.

Ratcliffe, D. A. 1993. The Peregrine Falcon. T and AD Poyser, London.

Sabo, B. E., and **R. C. Laybourne.** 1994. Preparation of avian material recovered from pellets and as prey remains. Journal of Raptor Research 28: 192–193.

SAS Institute. 1995. JMP Users Guide Version 3.1. Cary, North Carolina.

Squires, J. R., S. H. Anderson, and **R. Oakleaf.** 1991. Prairie Falcons quit nesting in response to spring snowstorm. Journal of Field Ornithology 62: 191–194.

Steidl, R. J., C. R. Griffin, L. J. Niles, and **K. E. Clark.** 1991. Reproductive success and eggshell thinning of a reestablished Peregrine Falcon population. Journal of Wildlife Management 55: 294–299.

Thiollay, J. M. 1988. Prey availability limiting an island population of Peregrine Falcons in Tunisia. Pages 701–710 *in* Peregrine Falcon populations: their management and recovery. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund Inc., Boise.

United States Department of Agriculture. 1993. The national hierarchical framework of ecological units ECOMAP. U.S. Department of Agriculture, Washington, DC.

United States Fish and Wildlife Service. 1991. Revised Peregrine Falcon eastern population recovery plan. U.S. Fish and Wildlife Service, Newton Corner, Massachusetts.

Wootton, J. T., and **D. A. Bell.** 1992. A metapopulation model of the Peregrine Falcon in California: viability and management strategies. Ecological Applications 2: 307–321.

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Seasonal Changes in Arctic Hare, *Lepus arcticus*, Diet Composition and Differential Digestibility

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The composition of plant tissues in the stomach contents and faecal pellets of Arctic Hares (*Lepus arcticus*) on Banks Island was described for summer (July and August), early winter (November), mid-winter (February), and late winter (April) to assess seasonal differences in diet composition and relative differential digestibility of forage groups consumed. Hare diet was dominated by Arctic Willow (*Salix arctica*) throughout winter (*ca.* 78-95%); in summer the diet became more diverse and legumes (*Astragalus alpinus*, *Oxytropis Maydelliana*) predominated (*ca.* 70%). The proportion of forages in the diet determined by analysing stomach contents was not significantly different from that determined by analysing faecal pellets during all time periods. No forage classes were over- or under-represented in faecal pellets in any time period. Summer availability of willows on Banks Island could be substantially reduced following winters when high numbers of Arctic Hares and Muskoxen have been feeding on Arctic Willows.

Key Words: Arctic Hare, *Lepus arcticus*, Muskox, *Ovibos moschatus*, Peary Caribou, *Rangifer tarandus pearyi*, lemmings, *Dicrostonyx torquatus*, *Lemmus sibiricus*, diet, forage availability, digestibility, Banks Island, Northwest Territories.

On Banks Island, Peary Caribou (*Rangifer tarandus pearyi*), Muskoxen (*Ovibos moschatus*), Arctic Hares (*Lepus arcticus*), and Lemmings (*Dicrostonyx torquatus*, *Lemmus sibiricus*) are the only resident non-avian vertebrate herbivores. Peary Caribou and Muskoxen, the two major herbivores on Banks Island, show dramatic seasonal shifts in diet composition and diet overlap (Larter and Nagy 1997). As part of a study of seasonal range use and herbivory on Banks Island, I documented the diet of Arctic Hares during summer, early-, mid- and late-winter to: (1) determine what forages were consumed on a seasonal basis, (2) determine if differential digestibility of forages occurred during different seasons, and (3) document any potential impact Hares might have on forage availability for other resident herbivores.

Arctic Hare diet has previously been documented only three times; for summer and late-winter on Axel Heiberg Island, Northwest Territories (Parker 1977) and for summer and late-winter in northern Greenland (Klein and Bay 1991, 1995). There are no data on hare diet from the western High Arctic. Parker (1977) analysed plant fragments found in the stomachs of Arctic Hares shot in summer (3 July to 3 August) and late-winter (23 March to 6 May) to determine diet composition. Klein and Bay (1991) analysed plant fragments found in freshly deposited summer faecal pellets and from pellets assumed to have been deposited during the previous winter to determine diet composition.

Klein and Bay (1995) compared summer diet composition of Arctic Hares determined by analysing plant fragments found in faeces with plant fragments found in stomachs. They indicated that summer diet composition of Arctic Hares determined by the analysis of faecal plant fragments, required correcting because of differential digestibility of forages. Whether or not to correct for differential digestibility in winter diets was discussed but not resolved (Klein and Bay 1991, 1995). Larter and Nagy (1996*) showed little difference in the February diet of Barren-Ground Caribou (*Rangifer tarandus*) when diet was determined either by the analysis of plant fragments in the rumen or the plant fragments in the faeces, and questioned whether differential digestibility was an issue during winter. Use of a correction factor for diet composition determined during summer may be inappropriate for winter.

Forage availability is reduced by snow cover and herbivore foraging during winter. Winter occurs during most of the year in the High Arctic. Larter and Nagy (1997) documented increased winter use of willows by Muskoxen on Banks Island during the 1990s when compared to the 1970s. The Muskoxen population had increased from *ca.* 3800 in 1972 to *ca.* 65 000 non-calves in 1994. Peary Caribou utilize willows during summer as a primary food source. Willow comprises ≥ 80% of the July and ≥ 40% of the June and August diet of Caribou (Larter and Nagy 1997; N. Larter and J. Nagy *unpublished data*). Reductions in summer willow availability,

*References marked with asteriz (*) are listed in separate Documents Cited section.

FIGURE 1. The study area, Banks Island, Northwest Territories. All hares were collected in upland habitats during travel between Sachs Harbour, Camp Coyote and Camp Bernard.

caused by increased cropping of willows during winter, could affect the Caribou population. The potential impact of small mammal herbivory on the dynamics of forage availability has largely gone unreported.

In the present communication I: (1) document seasonal changes in the diet of Arctic Hares on Banks Island obtained by analysing plant fragments in faeces and the stomach, (2) assess differential digestibility of forage groups on a seasonal basis by comparing plant fragments found in the faeces and the stomach, and compare my findings with those of Klein and Bay (1995), and (3) discuss the potential impact hares may have on forage availability for other resident herbivores of Banks Island. Botanical nomenclature follows Hultén (1990).

Study Area

Banks Island is the most western island in the Canadian Arctic Archipelago and covers an area of approximately 70 000 km^2 (Figure 1). The climate is Arctic maritime along coastal areas where weather stations are located, tending toward Arctic desert inland. Winters are long, mean monthly temperatures are below 0°C from September through May, and cold, mean minimum daily temperatures range from –30° to –40°C from December to March. Summers are short and cool, mean maximum daily temperatures range from 5° to 10°C from June through August. Precipitation is low with an annual mean of 9 cm (Zoltai et al. 1980*). Sachs Harbour is the only permanent settlement on the Island (71° 59′ N, 125° 17′ W), with a population of 125.

Habitat types have been adapted from Kevan (1974), Wilkinson et al. (1976), and Ferguson (1991). There are four major terrestrial habitats: (1) wet-sedge meadow; (2) upland barren; (3) hummock tundra; and (4) stony barren. Wet-sedge meadows generally are level hydric lowlands characterized by Water Sedge (*Carex aquatilis*), Cotton Sedge (*Eriophorum scheuchzeri*), and Tundra Grass (*Dupontia fisheri*). Upland barrens are moist well-drained sites occurring on the upper and middle parts of slopes. Vegetation is dominated by Mountain Avens (*Dryas integrifolia*) and Arctic Willow (*Salix arctica*) with legumes and a variety of forbs also present. Hummock tundra occurs on moderately steep slopes characterized by individual hummocks, which are vegetated primarily by dwarf shrubs including Mountain Avens, Arctic Willow and Arctic Heather (*Cassiope tetragona*); legumes and a variety of forbs are also present. Stony barrens are sparsely vegetated (< 10% cover) with a coarse gravelly substrate. This habitat is located on wind-blown areas, ridges, gravel and sand bars.

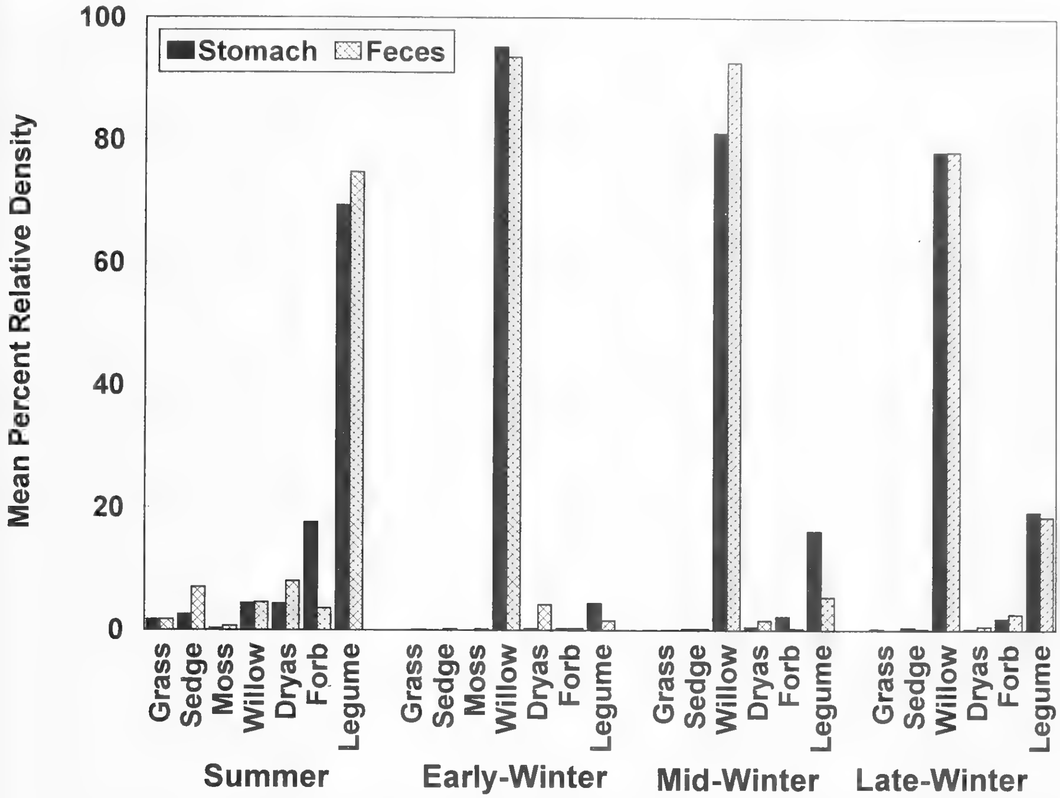

FIGURE 2. Summer, early-, mid-, and late-winter diets of Arctic Hares on Banks Island determined from analyses of plant fragments found in stomach contents and faecal pellets.

In 1994, numbers of Peary Caribou appeared to have stabilized at *ca.* 800 while Muskoxen numbers had increased to *ca.* 65 000 non-calves (Larter and Nagy 1997; Nagy et al. 1996). Local and scientific knowledge indicate that numbers of Arctic Hares show periodic noncyclical highs. Based upon the Inuvialuit Harvest Study Program Arctic Hares are currently high (1996-1998) and were high from 1986-1988 and from 1992-1994. Lemming numbers have shown a four-year cyclical pattern with high densities during the summers of 1993 and 1997 (Larter 1998*).

Methods

During field work conducted periodically on south central Banks Island (72° 12' N, 123° 30' W) from July 1993 through April 1997, 17 Arctic Hares were shot: 3 during summer (July and August), 3 during early winter (November), 8 during mid-winter (February), and 3 during late winter (April). Whole stomachs and faecal pellets, collected from rectal/colon area, were collected from each animal and kept frozen until transported to the laboratory in Inuvik. Stomach contents were removed. Stomach contents and faecal pellets were air dried for 48 h to remove excess water, oven dried at 60°C for 48 h and then ground (0.1 mm screen). A mixed ≤2 g subsample was analysed micro-histologically (Sparkes and Malechek 1968), following the method outlined in Hansen et al. (1976*) at the Composition Analysis Laboratory, Ft. Collins, Colorado. Microscope slides prepared from each sample were examined within 100 fields of view to differentiate plant tissues. Data are presented as mean percent relative density of plant fragments. Major forage classes were grass, sedge, legume (*Astragalus alpinus*, *Oxytropis Maydelliana*), willow, Mountain Avens, forb, and moss. One sample had unidentified forb material in it (0.47%) and was placed in the forb class for the analysis.

I used the Wilcoxon signed-rank test (Conover 1980) to compare forage class proportions determined from stomach samples with forage class proportions determined from faecal pellets for all four time periods. Moss was absent in mid- and late-winter diets, therefore it was not included in the statistical analyses for those time periods. Since forage classes were not independent and to provide a better comparison, I reanalysed Klein and Bay's (1995) data using the Wilcoxon signed-rank test.

Results

All hares were shot in either upland barren or hummock tundra habitats regardless of season. Summer diet of Arctic Hares was the most diverse and was dominated by legumes (mean 69.3 and 74.7% as determined from stomach contents and faecal pellets, respectively). Early-winter diet was almost exclusively willow (mean 95.2 and 93.5% as determined from stomach contents and faecal pellets, respectively). Willow predominated in the diet in mid- and late-winter, while legumes increased in the diet as winter progressed to *ca.* 20% in late- winter (Figure 2). The proportions of each forage group in the diet determined from stomach contents, were not significantly (P>0.05) different from those determined from faecal pellets within any of the four time periods. No forage classes were over- or under-represented in faecal pellets in any time period.

Reanalysis of Klein and Bay's (1995) data using the Wilcoxon signed-rank test concurred differential digestibility of forage classes. Forbs were significantly (P<0.05) under-represented in the faeces, while both sedge and grass were significantly (P<0.05) over-represented in the faeces.

Discussion

Summer (July and August) diets of Arctic Hares were documented from Axel Heiberg Island, N.W.T., by analysing stomach contents (Parker 1977), and from northern Greenland, by analysing both stomach contents and faecal pellets (Klein and Bay 1991, 1995). As in this study, summer diets were a mix of grass, sedge, and forbs (including legumes), with <20% willow. Grass was a greater proportion (>40%) and forbs (including legumes) were a lesser proportion (<35%) of the hare diet on Axel Heiberg Island and in northern Greenland (Parker 1977; Klein and Bay 1995). On Banks Island, grass was minor (<2%) proportion of the diet; forbs (including legumes) were the greatest proportion (>75%). The low proportion of forbs in the diet of hares from northern Greenland and Axel Heiberg Island may result from low availability. Legumes are absent in Greenland north of *ca* 75°N latitude (D. Klein, personal communication) and are absent on Axel Heiberg Island (M. Raillard, personal communication). The low proportions of grass and high proportions of forbs (including legumes) on Banks Island may be related to availability. Grass was only present in 21% of 1474, 0.125 m^2 plots randomly located in the four major terrestrial habitats of Banks Island during range work in the 1990s while 66% of those same 1474 plots contained forbs (including legumes) (N. Larter, unpublished data). Forage availability, other than sedge, was not addressed in other studies of hare diets (Parker 1977; Klein and Bay 1991, 1995).

Hare diets in winter have been documented for late-winter (23 March–6 May) on Axel Heiberg Island, N.W.T. (Parker 1977) and for samples assumed to have been pooled over the entire winter from northern Greenland (Klein and Bay 1991). Willow dominated the late-winter diet on both Banks and Axel Heiberg Islands, however the late-winter diet on Axel Heiberg Island was almost exclusively willow (>92%). Early- and mid-winter diets of hares on Banks Island were almost exclusively willow, but by late-winter willow was *ca.* 80% of the diet. Willow generally represents a substantial amount of above ground biomass in all habitats year round and was present in 29% (423 of 1474) of plots in the four major terrestrial habitats of Banks Island (N. Larter, unpublished data). The winter diet of hares from northern Greenland was mostly forb (*ca.* 50%) and willow (*ca.* 40%) with some graminoids (*ca.* 10%). However, because all winter faecal pellets were collected in the following summer and pooled, comparisons to my results are limited.

The difference between Klein and Bay's (1995) findings of differential digestibility of summer forages consumed by hares, and my findings may have been a result of: (1) reduced sample size, (2) different numbers of forage classes used in the analyses, (3) the diet of Banks Island hares being dominated by two forage classes (legumes in particular), or (4) a real lack of differential digestibility in the forages consumed. Klein and Bay (1995) had a larger number of summer samples (n = 10) than my study (n = 3) and my samples showed little individual variation in diet. Klein and Bay (1995) included six forage classes in their analysis (grass, sedge, moss, willow, dryas, and forb), while I subdivided the forb class into forb and legume and had seven classes in the analysis. To determine what effect the number of forage classes had, I combined my forb and legume classes and reanalysed the data. The results showed the forb (including legumes) class was under-represented in the faeces by only 8% (P = 0.10), compared to a 78% under-representation (P = 0.015) found by Klein and Bay (1995). The summer diet of hares on Banks Island was more diverse than winter, but not as diverse as that of hares in northern Greenland. No single forage class made up $\geq$55% of the summer diet of hares in Greenland, while a single forage class made up at least 77% of the summer diet of hares on Banks Island.

Differential digestibility of forages, in particular dicots, has been documented for Collared Lemmings (Rodgers and Lewis 1985). Collared lemmings selected dicots over monocots in feeding preference trials (Batzli and Jung 1980). Based upon the low proportion of sedge in the diet of Arctic Hares in northern Greenland and Axel Heiberg Island relative to sedge availability (Parker 1977; Klein and Bay 1994), and the apparently low digestibility of sedge, Klein and Bay (1995) suggested that Arctic Hares are not adapted to use sedge. Sedge use by hares on Banks Island was negligible and availability was high; 75% (1104 of 1474) of the vegetation plots contained sedge (N. Larter, unpublished data). The lack of sedge and the prominence of willow and legume in the Banks Island Arctic Hare diet is consistent with their suggestion.

The lack of differential digestibility in forages during winter is likely related to forage quality. During winter all forages are essentially freeze-dried and weathered, relatively more fibrous and less protein-rich, and therefore of low quality (Klein 1977). Studies determining the differential digestibility of forages have been generally conducted during the growing season when there is a wide range in forage quality levels between plants and within plant parts (Voth and Black 1973). Correcting for diet composition data determined from differential digestibility during summer should be limited to summer data only.

When populations are high, herds of hundreds of Arctic Hares are common on hillsides during winter and summer (J. Lucas Sr., personal communication; personal observation). During winter, hares use their sharp claws and protruding incisors to remove snow and access forage. Given a winter diet almost exclusively of willow, high hare numbers could potentially consume substantial amounts of willow from hillsides during the dormant season. In the winter diet of Muskoxen during the mid-1990s, willow use was 2–3 times greater than that found in the early-1970s (Wilkinson et al. 1976; Shank et al. 1978; Larter and Nagy 1997) and over the same time period the Muskoxen population had increased 16-fold. The combination of high hare numbers and current Muskoxen numbers may result in winter browsing levels that severely impact summer willow availability by either the physical removal of plant biomass during the dormant season and/or increasing plant mortality due to continued cropping of the previous years growth. Reduced new growth of willows during summer may affect the Peary Caribou population which rely on this growth as a primary food source during summer (Larter and Nagy 1997). Summer diet of Collared Lemmings during peak numbers is almost exclusively Mountain Avens (Larter 1998*). The availability of Mountain Avens is high (70% of 1474 vegetation plots: N. Larter, unpublished data) and they are a small proportion of the diets of Arctic Hares, Muskoxen and Peary Caribou. Therefore, high numbers of this small resident herbivore may have some localized effect on forage availability, but impacts would be minimal on hares, Muskoxen and Caribou.

The diet of Arctic Hares on Banks Island is dominated by willow and legume throughout all seasons. The abundance of dicots and lack of monocots in the diet is more striking than that found in hare diets on northern Greenland and Axel Heiberg Island. Legume abundance may be unique to Banks Island as they are absent in the High Arctic of Greenland and Canada. The lack of apparent differential digestibility of forages during winter is similar to that found for Barren-ground Caribou (Larter and Nagy 1996*). Therefore, a correction factor for winter diets determined from faecal pellets based upon differential digestibility may well be unnecessary, especially for Banks Island. A correction factor for summer diets determined from faecal pellets may be warranted. Additional sampling and consideration of the role of caecotrophy are required to address this issue. However, given such a predominance of legume and forb in the summer diet of Banks Island Hares, the practical utility of a correction factor may be limited. Winter foraging by high numbers of Arctic Hares in combination with current levels of winter foraging by Muskoxen could reduce the availability of willow in summer for Peary Caribou.

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Documents Cited [marked * in text citations]

Hansen, R. M., T. M. Foppe, M. B. Gilbert, R. C. Clarke, and **H. W. Reynolds.** 1976. The microhistological analyses of feces as an estimator of herbivore diet. Unpublished report, Department of Range Science, Colorado State University, Fort Collins. 7 pages.

Larter, N. C. 1998. Collared lemming abundance, diet, and morphometrics on Banks Island, 1993-1996. Manuscript Report Number 107, Government of the Northwest Territories Department of Resources, Wildlife & Economic Development, Yellowknife, Northwest Territories. 21 pages.

Larter, N. C., and **J. A. Nagy.** 1996. Bluenose caribou community harvest Eskimo Lakes area, February 1995. Manuscript Report Number 88, Government of the Northwest Territories, Department of Renewable Resources, Yellowknife, Northwest Territories. 30 pages.

Zoltai, S. C., D. J. Karasiuk, and **G. W. Scotter.** 1980. A natural resource survey of the Thomsen River area, Banks Island, Northwest Territories. Unpublished Report of Canadian Parks Service, Ottawa. 153 pages.

Literature Cited

Batzli, G. O., and **H. G. Jung.** 1980. Nutritional ecology of microtine rodents: Digestibility of forage. Journal of Mammalogy 60: 740–750.

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons Inc. New York. 493 pages.

Ferguson, R. S. 1991. Detection and classification of muskox habitat on Banks Island, Northwest Territories, Canada, using landsat thematic mapper data. Arctic 44: 66–74.

Hultén, E. 1990. Flora of Alaska and neighboring territories. Stanford University Press, Stanford, California, 1008 pages.

Kevan, P. G. 1974. Peary caribou and muskoxen on Banks Island. Arctic 27: 256–264.

Klein, D. R. 1977. Winter food preferences of snowshoe hares (*Lepus americanus*) in interior Alaska. Proceedings of the International Congress of Game Biology 13: 266–275.

Klein, D. R., and **C. Bay.** 1991. Diet selection by vertebrate herbivores in the high arctic of Greenland. Holarctic Ecology 14: 152–155.

Klein, D. R., and **C. Bay.** 1994. Resource partitioning by mammalian herbivores in the High Arctic. Oecologia 97: 439–450.

Klein, D. R., and **C. Bay.** 1995. Digestibility of forage types by arctic hares. Ecoscience 2: 100–102.

Larter, N. C., and **J. A. Nagy.** 1997. Peary caribou, muskoxen, and Banks Island forage: assessing seasonal diet similarities. Rangifer 17: 9–16.

Nagy, J. A., N. C. Larter, and **V. P. Fraser.** 1996. Population demography of Peary caribou and muskox on Banks Island, N.W.T., 1982–1992. Rangifer Special Edition 9: 213–222.

Parker, G. R. 1977. Morphology, reproduction, diet, and behavior of the arctic hare (*Lepus arcticus monstrabilis*) on Axel Heiberg Island, Northwest Territories. Canadian Field-Naturalist 91: 8–18.

Rodgers, A. R., and **M. C. Lewis.** 1985. Diet selection in arctic lemmings (*Lemmus sibiricus* and *Dicrostonyx groenlandicus*): food preferences. Canadian Journal of Zoology 63: 1161–1173.

Shank, C. C., P. F. Wilkinson, and **D. F. Penner.** 1978. Diet of Peary caribou, Banks Island, N.W.T. Arctic 31: 125–132.

Sparkes, D. R., and **J. C. Malechek.** 1968. Estimating percentage dry weight diets using a microscopic technique. Journal of Range Management 21: 264–265.

Voth, E. H., and **H. C. Black.** 1973. A histologic technique for determining feeding habits of small herbivores. Journal of Wildlife Management 37: 223–231.

Wilkinson, P. F., C. C. Shank, and **D. F. Penner.** 1976. Muskox-caribou summer range relations on Banks Island, N.W.T. Journal of Wildlife Management 40: 151–162.

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Effects of Woody Vegetation on Prairie Wetland Birds

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Bird surveys were conducted in wetlands (n = 1000) throughout South Dakota during the summers of 1995 and 1996 to assess effects of woody vegetation encroachment on nongame wetland bird species. Wetland bird species richness decreased as the extent of woody vegetation encompassing wetland perimeters increased. Logistic analyses indicated that four wetland bird species (Black Tern [*Chlidonias niger*], Wilson's Phalarope [*Phalaropus tricolor*], Eared Grebe [*Podiceps nigricollis*], Red-winged Blackbird [*Agelaius phoeniceus*]) were less likely to occur in wetlands surrounded by trees. The only birds using trees surrounding wetlands were edge species that thrive without the aid of management. We estimate that 35 560 wetlands in eastern South Dakota alone may have wetland bird populations which are negatively impacted by encroachment of woody vegetation. Wetland managers should consider limiting the extent of woody vegetation around prairie wetlands when nongame wetland bird production is the management goal.

Key Words: Edge species, prairie wetland birds, wetlands, woody vegetation, northern Great Plains, South Dakota.

Woody vegetation in the northern Great Plains historically grew as strips along streams, on islands within lakes, and in small patches along the leeward edges of wetlands that were protected from fires (Higgins 1986). In a little over a century, this region has been transformed from a contiguous expanse of wetlands and grasslands into a highly fragmented, agricultural landscape that is less conducive to wetland bird production. Population declines of several wetland birds have coincided with human-induced alterations such as wetland drainage, tillage of associated uplands, and the cessation of large-scale natural disturbances such as fire and grazing.

Suppression of natural disturbances that historically deterred woody-species growth around wetlands has enabled willow (*Salix* spp.) and Eastern Cottonwood (*Populus deltoides*) to colonize entire wetland perimeters. Although research has been conducted to evaluate bird use of wetland vegetation (e.g., Weller and Spatcher 1965; Murkin et al. 1997) and the effects of wetland area and isolation on wetland bird communities (Brown and Dinsmore 1986; Gibbs et al. 1991; Craig and Beal 1992), research concerning the effects of woody vegetation on prairie wetland birds is lacking. The objective of this study was to evaluate the effects of woody vegetation on prairie wetland birds by addressing four questions:

(1) Does wetland-bird species-richness decrease with an increase in extent of woody vegetation encompassing wetlands?
(2) Which wetland bird species are less likely to occur in wetlands encompassed by woody vegetation?
(3) Is there a trade-off whereby encroachment of woody vegetation results in newly created habitat for forest birds of management concern despite a loss of wetland habitat for nongame wetland birds?
(4) How many wetlands in South Dakota may have wetland bird populations that are negatively impacted by the encroachment of woody vegetation?

Study Area and Methods

Study design

We overlayed a grid of ~3800, 25.9 km^2 (10 mi^2) cells onto a geographic information system (GIS) that was constructed from National Wetland Inventory (NWI) data for eastern South Dakota (Johnson and Higgins 1997). Cells (n = 216) were randomly selected from seven physiographic regions in eastern South Dakota (Johnson et al. 1995) in 1995 and 1996. Forty cells within four of five physiographic regions in western South Dakota were selected in 1996 using 7.5′ NWI maps. Wetlands that lie west of the Missouri River have not yet been digitized into a GIS. We excluded the forested Black Hills physiographic region in western South Dakota from our study area.

An average of two seasonal and two semipermanent wetlands (Stewart and Kantrud 1971) were surveyed within each cell. Wetlands that were sorted by area within cells were systematically selected using a random starting point to ensure an adequate sample of all wetland sizes were surveyed. Wetlands were surveyed after 1175 landowners were contacted to obtain permission to work with wetlands on private lands.

Area (ha) of surveyed wetlands in eastern South Dakota was estimated using the wetland GIS. We planimetered NWI maps to estimate area of wetlands surveyed in western South Dakota. Proportion of wetland area containing emergent vegetation was estimated visually during surveys using the Daubenmire (1959) scale in which the entire wetland was treated as a single quadrat (Bailey and Poulton 1968). Class intervals describing the percentage of vegetated area within wetlands were: (1) 0; (2) 1; (3) 2-5; (4) 6-25; (5) 26-50; (6) 51-75; (7) 76-95; (8) > 95.

Wetland bird survey methodology and preliminary accuracy assessments

Species lists were compiled for breeding nongame wetland bird species that were seen or heard during 8-minute surveys (Scott and Ramsey 1981; Fuller and Langslow 1984) within 18-m (0.1 ha) fixed radius circular-plots (Reynolds et al. 1980; Edwards et al. 1981; Brown and Dinsmore 1986). We defined breeding nongame wetland species as non-waterfowl (family Anatidae) species that nest in herbaceous vegetation within seasonal and semipermanent wetlands. Species that foraged in wetlands but which nested elsewhere (e.g. Great Blue Herons [*Ardea herodias*] and Double-crested Cormorants [*Phalacrocorax auritus*]) were excluded from richness estimates. In addition to recording conspicuous birds that were seen or heard during 8-minute surveys, we played tape recordings of Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), Least Bittern (*Ixobrychus exilis*), and American Bittern (*Botaurus lentiginosus*) calls to elicit responses from these secretive species (Marion et al. 1981; Johnson and Dinsmore 1986; Gibbs and Melvin 1993). A 3-minute, continuous-loop tape (Library of Natural Sounds, Cornell Laboratory of Ornithology, Ithaca, New York 14850) consisting of 25 seconds of male territorial vocalizations of each of four species, interspersed with five seconds of silence, was played for two minutes at each circular plot. The third minute of calling repeated 10 seconds of vocalizations of each species, interspersed with five seconds of silence. Recordings were played during the 3-5 minute period of each 8-minute survey. Vocalizations of Soras included "kerwee" and whinny calls. Both "kiddick" and grunt calls of Virginia Rails were broadcast.

Number of circular-plots used in surveys increased with increasing wetland area and complexity of wetland vegetation (Brown and Dinsmore 1986). A maximum of four circular-plots was used to survey birds in each wetland. Plots were dispersed throughout the wetland to facilitate sampling within multiple types of vegetation. Coverage of the total wetland area varied from nearly 100% in small wetlands to < 1% in large wetlands. When no vegetation was present, circular-plots were placed near the wetland edge and birds were surveyed before approaching the wetland. Species detected outside of circular-plots during surveys or while moving between plots were recorded (Brown and Dinsmore 1986; Hemesath and Dinsmore 1993). We also traversed wetland perimeters to ensure that each species present was recorded. Wetlands were classified as used by a particular species if we observed adults, active nests, or young. Surveys were conducted when birds were most active (sunrise to 10:00 h and 18:00 h to sunset [Verner and Ritter 1986]). Surveys were not conducted during rainy or windy (≥ 24 km/h) days.

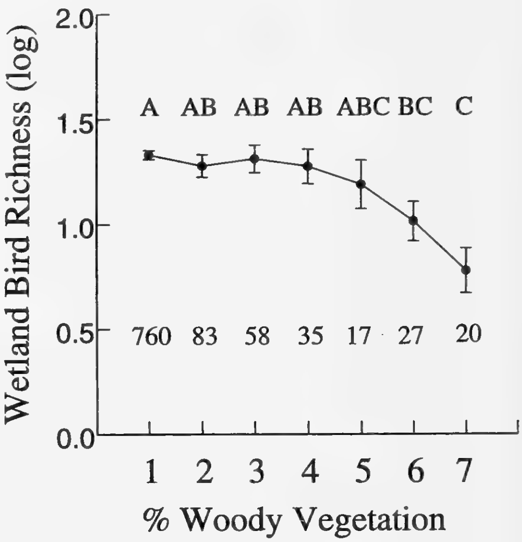

FIGURE 1. Average nongame wetland bird species richness within seven classes that describe the extent of the wetland perimeter encompassed by woody vegetation. Classes on the *x*-axis correspond to the following percentages: (1) < 1%; (2) 1-5; (3) 6-25; (4) 26-50; (5) 51-75; (6) 76-95; (7) > 95%. Bird species richness decreases as extent of the wetland perimeter encompassed by trees increases. Number of wetlands within each class interval are adjacent to the standard error bars. Means denoted by the same letter do not differ ($P < 0.05$).

Survey methodology followed an established sampling protocol that has been used extensively to survey wetland birds (Brown and Dinsmore 1986; Hemesath and Dinsmore 1993; VanRees-Siewert and Dinsmore 1996; Naugle et al. *in press*). Despite widespread use of methods in this study, some investigators believe that use of a variable number of circular plots may bias survey results because observers spend more time surveying larger wetlands. Therefore, we conducted preliminary accuracy assessments of our methods by surveying a random sub-set of 20 wetlands twice within the same sampling season to determine how effectively a single survey characterized wetland bird occupancy rates

TABLE 1. Coefficients from logistic regression analyses used to determine whether occurrences of 14 nongame wetland bird species were related to extent of woody vegetation surrounding wetlands in South Dakota, 1995 and 1996. A negative coefficient (β_1) indicates that a particular species was less likely to occur in wetlands surrounded by woody vegetation. Wetland area and proportion of vegetated wetland area were additional independent variables included in logistic regressions.

Species	Woody Vegetation β_1	SE	P
Wilson's Phalarope *Phalaropus tricolor*	- 0.72	0.12	0.00
Eared Grebe *Podiceps nigricollis*	- 0.60	0.19	0.00
Red-winged Blackbird *Agelaius phoeniceus*	- 0.32	0.05	0.00
Black Tern *Chlidonias niger*	- 0.17	0.06	0.01
American Coot *Fulica americana*	- 0.08	0.05	0.09
American Bittern *Botaurus lentiginosus*	- 0.13	0.09	0.15
Sora *Porzana carolina*	- 0.02	0.04	0.60
Pied-billed Grebe *Podilymbus podiceps*	+ 0.01	0.06	0.99
Western Grebe *Aechmophorus occidentalis*	+ 0.02	0.18	0.91
Yellow-headed Blackbird *Xanthocephalus xanthocephalus*	+ 0.02	0.04	0.58
Virginia Rail *Rallus limicola*	+ 0.05	0.05	0.35
Swamp Sparrow *Melospiza georgiana*	+ 0.11	0.09	0.21
Least Bittern *Ixobrychus exilis*	+ 0.20	0.15	0.20
Marsh Wren *Cistothorus palustris*	+ 0.11	0.04	0.01

and to determine whether the length of time observers spent within wetlands influenced species detection. Each second survey was conducted by an observer who did not have prior knowledge of the species that were recorded during the first survey. Observers who surveyed wetlands a second time recorded birds for 32 min (the length of time required to complete four circular-plots in large wetlands) in smaller wetlands in which < 4 circular plots were used (n = 15). We detected 93.3% of the wetland bird species that were recorded during two surveys in the first survey. No additional wetland bird species were detected when observers remained at smaller wetlands for a time equal to that spent at larger wetlands. Positive results regarding preliminary accuracy assessments enabled us to survey wetlands once in 1995 or 1996 to obtain a large sample over an extensive geographic region rather than surveying a small number of localized wetlands multiple times (Meentemeyer 1989). The modification in survey sampling intensity resulted in an increased number of wetlands surveyed, which provided adequate sample sizes for logistic regression analyses (Hosmer and Lemeshow 1989).

Surveys of bird species using trees along wetland perimeters

Species lists also were compiled for birds that were seen or heard in woody vegetation along wetland perimeters. In addition to noting any bird species that flushed from trees (e.g. hawks and owls), we traversed the wetland's edge where trees were present to ensure that species using woody vegetation were recorded. Species in woody vegetation were easily detected because trees surrounding wetlands typically grew around the wetland perimeter in single rows. Proportion of the wetland perimeter that had woody vegetation was estimated visually in categories: (1) < 1; (2) 1-5; (3) 6-25; (4) 26-50; (5) 51-75; (6) 76-95; (7) > 95.

Statistical analyses

Analysis of covariance was used to determine whether wetland bird species richness was related to the extent of woody vegetation along wetland edges. Two additional variables (wetland area, vegetated wetland area) that have long been known to influence wetland bird species richness (Weller and Spatcher 1965; Brown and Dinsmore 1986; Gibbs et al. 1991; Craig and Beal 1992; Murkin et al. 1997) were used as covariates to remove non-treatment effects from our richness estimates. A Tukey's pairwise mean comparison test was used to determine where differences in species richness occurred among categories. Wetland bird species richness estimates and wetland areas were log-transformed to approximate normality.

Logistic regression analysis (Hosmer and Lemeshow 1989) was used to investigate the influence of woody vegetation on the presence of individual wetland bird species. To evaluate whether the probability of occurrence of individual species was related to the extent of woody vegetation within the wetland perimeter (x_{1i}), wetland area (x_{2i}), or vegetated wetland area (x_{3i}), we used the model:

$$P(y_i = 1) = \frac{\exp(\beta_0, + \beta_1 \chi_{1i} + \beta_2 \chi_{2i} \ldots)}{1 + \exp(\beta_0, + \beta_1 \chi_{1i} + \beta_2 \chi_{2i} \ldots)}$$

where $P(y_i = 1)$ is the probability of the particular species being present in wetland i and β_0, β_1, β_2, and β_3 are model parameters to be estimated. Significance of each regression was tested using the Wald chi-square statistic (maximum likelihood esti-

TABLE 2. Bird species occurrence in the 47 wetlands that were >75% encompassed by woody vegetation, South Dakota, 1995 and 1996.

Species[a]	Number of wetlands in which species occurred	% Occurrence[b]
Eastern Kingbird *Tyrannus tyrannus*	30	63.8
Common Grackle *Quiscalus quiscula*	28	59.6
Mourning Dove *Zenaida macroura*	24	51.1
Common Yellowthroat *Geothlypis trichas*	24	51.1
Song Sparrow *Melospiza melodia*	21	44.7
American Goldfinch *Carduelis tristis*	18	38.3
Brown-headed Cowbird *Molothrus ater*	17	36.2
Yellow Warbler *Dendroica petechia*	17	36.2
Empidonax spp.	14	29.8
American Robin *Turdus migratorius*	12	25.5
Orchard Oriole *Icterus spurius*	9	19.1
Brown Thrasher *Toxostoma rufum*	9	19.1
Vireo spp.	9	19.1
Raptors[c]	7	14.9
House Wren *Troglodytes aedon*	7	14.9
Western Kingbird *Tyrannus verticalis*	6	12.8
Baltimore Oriole *Icterus galbula*	5	10.6
European Starling *Sturnus vulgaris*	5	10.6

[a]Species recorded < 5 times were omitted.
[b]Number of wetlands in which a species was present was divided by 47 and multiplied by 100 to determine occurrence rates.
[c]Species of raptors recorded were Red-tailed Hawk (*Buteo jamaicensis*), Swainson's Hawk (*Buteo swainsoni*), American Kestrel (*Falco sparverius*), and Great Horned Owl (*Bubo virginianus*).

mate). The 0.05 significance level was used for all statistical tests.

We used a conservative approach to estimate woodland bird species richness for three reasons: (1) to avoid masking the potential importance of woody vegetation to birds using trees, (2) because so few non-wetland, forest bird species were present in trees when wetlands were ≤ 75% encompassed by woody vegetation, and (3) because pairwise comparisons indicated that initial declines ($P < 0.05$) in wetland bird species richness were greatest for wetlands that were > 75% encompassed by trees (n = 47) (see results; Figure 1). Woodland bird species richness was calculated by dividing the number of species using trees surrounding wetlands by 47 rather than 1000 (total sample size). Number of wetlands in which a particular species occurred also was divided by 47 and multiplied by 100 to determine percent occurrence/species.

Total numbers of seasonal (n = 334 699) and natural, semipermanent (n = 24 485) wetlands throughout eastern South Dakota have been previously estimated using the wetland GIS (Johnson and Higgins 1997). We multiplied the proportion of wetlands that were encompassed by woody vegetation in this study (see Figure 1 for sample sizes) by total wetland numbers to estimate the number of seasonal and semipermanent wetlands that are either > 25% or > 75% surrounded by trees in all of eastern South Dakota.

Results

Wetland bird species richness decreased as the extent of woody vegetation encompassing wetland perimeters increased ($F = 5.385$, 6 df, $P < 0.001$) (Figure 1). An initial decline in wetland bird species richness occurs when wetland perimeters are > 25% surrounded by woody vegetation (Figure 1). Pairwise comparisons indicated that most of the significant declines ($P < 0.05$) in wetland bird species richness occurred when wetlands were > 75% encompassed by woody vegetation (all possible comparisons depicted in Figure 1). Designated covariates (wetland area [$F = 509.234$, 1 df, $P < 0.001$] and vegetated wetland area [$F = 67.818$, 1 df, $P < 0.001$]) removed significant portions of explained variation that were not attributable to effects of woody vegetation.

Occurrence of four wetland bird species (Black Tern [*Chlidonias niger*], Wilson's Phalarope [*Phalaropus tricolor*], Eared Grebe [*Podiceps nigricollis*], Red-winged Blackbird [*Agelaius phoeniceus*]) was negatively related to extent of woody vegetation encroachment (Table 1). The occurrence of Marsh Wrens (*Cistothorus palustris*) was positively related to presence of woody vegetation (Table 1).

Ninety-nine (9.9%) wetlands had perimeters that were > 25% surrounded by woody vegetation (Figure 1). Forty-seven (4.7%) of the wetlands had perimeters that were > 75% surrounded by woody vegetation (Figure 1). An average of six woodland bird species (Range = 1-12, SE = 0.461) was detected in the trees surrounding the 47 wetlands whose perimeters were > 75% encompassed with woody vegetation (Table 2). Four species (Eastern Kingbird [*Tyrannus tyrannus*], Common Grackle [*Quiscalus quiscula*], Mourning Dove [*Zenaida macroura*], Common Yellowthroat [*Geothlypis trichas*]) were recorded using woody vegetation in at least half of the wetlands with perimeters that were > 75% encompassed by trees. An estimated 35 560 seasonal and semipermanent wetlands in eastern South Dakota are > 25% surrounded by woody vegetation, of which 16 882 have perimeters that are > 75% encompassed by trees.

Discussion

Wetlands throughout South Dakota provided nesting habitat for a diverse assemblage of nongame wetland bird species. Our results indicate, however, that encroachment of woody vegetation surrounding prairie wetlands is decreasing overall richness of nongame wetland birds. Furthermore, two of the four species that were less likely to use wetlands surrounded by trees (Black Terns, Eared Grebes) are area-sensitive species that require large wetlands for nesting (Brown and Dinsmore 1986; Naugle 1997; Naugle et al. *in press*). Marsh Wrens, the only wetland bird species that was positively related to the presence of woody vegetation in this study, are a widely distributed species which usually nests in dense wetland vegetation that may include woody-stemmed plants (Willson 1967). Although waterfowl (family Anatidae) were not included in this study, Rumble and Flake (1983) found that stock-watering ponds in western South Dakota that were encompassed by trees had fewer waterfowl broods. Mechanisms limiting bird use of prairie wetlands encompassed by trees are poorly understood; however, woody vegetation encompassing wetlands in our study provided perches for predatory raptors (e.g. Red-tailed Hawks [*Buteo jamaicensis*]) and parasitic Brown-headed Cowbirds (*Molothrus ater*). Delphey and Dinsmore (1993) concluded that the presence of woody vegetation at natural wetlands and their relative scarcity among recently restored wetlands has led to a higher incidence of Brown-headed Cowbird parasitism of Red-winged Blackbird nests at natural wetlands.

Birds nesting and foraging in trees surrounding wetlands were predominantly edge species that thrive in disturbed habitats without the aid of management. Although several area-sensitive neotropical migrant species commonly nest in riparian forests > 100 m-wide (Keller et al. 1993), birds that we recorded in single rows of trees encompassing > 75% of the wetland perimeter were species that typically inhabit fragmented environments (e.g., forest/grassland edges, agricultural fields). As a result, the encroachment of woody vegetation decreases habitat availability for wetland bird species while further increasing the quantity of habitat for invading edge species (e.g., Saunders et al. 1991). Edge species that we recorded in woody vegetation also were some of the most abundant migratory and breeding species that have been found inhabiting treebelts in South Dakota (Martin 1980, 1981).

Small patches of woody vegetation in the northern Great Plains historically survived prairie fires within "fire shadows" (Higgins 1986). In the absence of natural disturbances such as fire and grazing that suppressed woody plant growth, the perimeters of numerous wetlands are becoming completely encompassed by willows and cottonwood. An extrapolation of the number of wetlands that are > 25% surrounded by woody vegetation in this study to total wetland numbers indicates that as many as 35 560 wetlands in eastern South Dakota alone may have wetland bird populations which are negatively impacted by woody vegetation. We recommend that wetland managers consider limiting the extent of woody vegetation encroachment when wetland bird production is the management goal. We further recommend that managers deter the rapid encroachment of woody vegetation encompassing restored wetlands (Delphey and Dinsmore 1993).

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Literature Cited

Bailey, A. W., and **C. E. Poulton.** 1968. Plant communities and environmental relationships in a portion of the Tillamook burn, Northwestern Oregon. Ecology 49: 1–13.

Brown, M., and **J. J. Dinsmore.** 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management 50: 392–397.

Craig, R. J., and **K. G. Beal.** 1992. The influence of habitat variables on marsh bird communities of the Connecticut River estuary. Wilson Bulletin 104: 295–311.

Daubenmire, R. F. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43–64.

Delphey, P. J., and **J. J. Dinsmore.** 1993. Breeding bird communities of recently restored and natural prairie potholes. Wetlands 13: 200–206.

Edwards, D. K., G. L. Dorsey, and **J. A. Crawford.** 1981. A comparison of three avian census methods. Studies in Avian Biology 6: 170–176.

Fuller, R. J., and **D. R. Langslow.** 1984. Estimating numbers of birds by point counts: how long should counts last? Bird Study 31: 195–202.

Gibbs, J. P., J. R. Longcore, D. G. McAuley, and **J. K. Ringelman.** 1991. Use of wetland habitats by selected nongame water birds in Maine. U.S. Fish Wildlife Service, Washington, D.C. Fish and Wildlife Research 9.

Gibbs, J. P., and **S. M. Melvin.** 1993. Call-response surveys for monitoring breeding waterbirds. Journal of Wildlife Management 57: 27–34.

Hemesath, L. M., and **J. J. Dinsmore.** 1993. Factors affecting bird colonization of restored wetlands. Prairie Naturalist 25: 1–11.

Higgins, K. F. 1986. Evidence of the historical occurrence of woody plants in areas of North Dakota grasslands. Pages 115–117 *in* Proceedings of the Ninth North American Prairie Conference. *Edited by* G. K. Clambey and W. C. Whitman. Tri-College University Center for Environmental Studies, Moorhead, Minnesota.

Hosmer, D. W., Jr., and **S. Lemeshow.** 1989. Applied logistic regression. Wiley, New York.

Johnson, R. R., and **J. J. Dinsmore.** 1986. The use of tape-recorded calls to count Virginia Rails and Soras. Wilson Bulletin 98: 303–306.

Johnson, R. R., and **K. F. Higgins.** 1997. Wetland resources of eastern South Dakota. South Dakota State University, Brookings, South Dakota.

Johnson, R. R., K. F. Higgins, and **D. E. Hubbard.** 1995. Using soils to delineate South Dakota physiographic regions. Great Plains Research 5: 309–322.

Keller, C. M. E., C. S. Robbins, and **J. S. Hatfield.** 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13: 137–144.

Marion, W. R., T. E. O'Meara, and **D. S. Maehr.** 1981. Use of playback recordings in sampling elusive or secretive birds. Studies in Avian Biology 6: 81–85.

Martin, T. E. 1980. Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. Condor 82: 430–439.

Martin, T. E. 1981. Limitation in small habitat islands: chance or competition? Auk 98: 715–734.

Meentemeyer, V. 1989. Geographical perspectives of space, time, and scale. Landscape Ecology 3: 163–173.

Murkin, H. R., E. J. Murkin, and **J. P. Ball.** 1997. Avian habitat selection and prairie wetland dynamics: a 10-year experiment. Ecological Applications 7: 1144–1159.

Naugle, D. E. 1997. Habitat area requirements of prairie wetland birds in eastern South Dakota. Ph.D. dissertation, South Dakota State University, Brookings, South Dakota.

Naugle, D. E., K. F. Higgins, S. M. Nusser, and **W. C. Johnson.** *in press.* Scale-dependent habitat use in three species of prairie wetland birds. Landscape Ecology.

Reynolds, R. T., J. M. Scott, and **R. A. Nussbaum.** 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309–313.

Rumble, M. A., and **L. D. Flake.** 1983. Management considerations to enhance use of stock ponds by waterfowl broods. Journal of Range Management 36: 691–694.

Saunders, D. A., R. J. Hobbs, and **C. R. Margules.** 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18–32.

Scott, J. M., and **F. L. Ramsey.** 1981. Length of count period as a possible source of bias in estimating bird densities. Studies in Avian Biology 6: 409–413.

Stewart, R. E., and **H. A. Kantrud.** 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildlife Service Resource Publication 92.

Vanrees-Siewart, K. L., and **J. J. Dinsmore.** 1996. Influence of wetland age on bird use of restored wetlands in Iowa. Wetlands 16: 577–582.

Verner, J., and **L. V. Ritter.** 1986. Hourly variation in morning point counts of birds. Auk 103: 117–124.

Weller, M. W., and **C. E. Spatcher.** 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa Agricultural Home Economics Experiment Station Special Report 43.

Willson, M. F. 1967. Notes on the interspecific behavioral relationships of marsh-nesting passerines. Auk 84: 118–120.

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Comparative Catch Efficiency of Amphibian Sampling Methods in Terrestrial Habitats in Southern New Brunswick

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Amphibians were sampled during two growing seasons in a variety of terrestrial habitats in the vicinity of Fundy National Park, New Brunswick. Four sampling methods were used: pitfall transects, pitfall arrays, quadrat searches, and time-constrained searches. Pitfall arrays sampled the greatest relative abundance and species richness of amphibians. However, quadrat searches were better at sampling *Plethodon cinereus* (Red-backed Salamander), a wholly terrestrial species.

Key Words: amphibians, terrestrial habitat, sampling methods, New Brunswick, Canada.

It has recently been suggested that amphibian populations are declining extensively, and perhaps globally (Blaustein and Wake 1990; Rabb 1990). Nevertheless, little is known about the current status of amphibian populations in most areas of Canada (Bishop et al. 1995). In view of concerns over such potential changes in this element of indigenous biodiversity, various agencies are proposing to conduct monitoring programs for amphibians. To aid in the design of such programs, we compared protocols for monitoring changes in the abundance of amphibians in a variety of terrestrial habitats in New Brunswick, where there are few data on amphibian populations or the quality of their habitats (McAlpine 1992).

Study Area

The fieldwork was done in or near Fundy National Park in southeastern New Brunswick. Although this park was established in 1948, it still has a legacy of prior land-uses, such as logging, agriculture, and introductions of non-indigenous species (Cooper and Clay 1994). In addition, substantial areas in the park are being used as campgrounds, a golf course, roads, trails, and other kinds of tourism-related infrastructure. These uses represent additional loss of natural habitat, and in some cases are barriers to movement. Natural stressors also are affecting the habitat mosaic, particularly damage to mature conifer forest caused by Spruce Budworm (*Choristoneura fumiferana*). Moreover, forestry plantations, clear-cuts, and agricultural land-uses at or near the park boundary are insularizing the protected area, with possible risks to its ecological integrity (Freedman et al. 1996; Woodley et al. 1998). In view of these ecological changes and concerns, Parks Canada is designing programs for monitoring indicators of the ecological integrity of Fundy National Park, including amphibian species and communities. This is the regional ecological context for the present study, which compares methods of monitoring amphibians in various terrestrial habitats.

Study Sites

We examined the following ten study sites (additional details are given in Adams 1997):

Site 1 — mixed-species angiosperm-conifer forest;
Site 2 — mixed-species angiosperm-conifer forest;
Site 3 — conifer-dominated forest with some overstory mortality caused by Spruce Budworm;
Site 4 — conifer-dominated forest with extensive overstory mortality caused by Spruce Budworm;
Site 5 — hardwood-dominated forest;
Site 6 — closed-canopy, Red Spruce (*Picea rubens*) plantation established in 1960 (36 years-old when studied);
Site 7 — closed-canopy, Jack Pine (*Pinus banksiana*) plantation, established in 1973 (23 years-old when studied);
Site 8 — partially open-canopy, Black Spruce (*Picea mariana*) plantation, established in 1976 (20 years-old when studied);
Site 9 — abandoned gravel pit partially revegetated by artificial seeding, with some incursions of native forbs and shrubs, and a breeding pond nearby in an excavated basin;
Site 10 — pasture abandoned about four decades previously.

All of the natural forest sites were located within the Park. All are mature, secondary forest, having been selectively logged in the past, but not within the past 50 years. The plantation at Site 6 was inside the park, having been established as a silvicultural trial. The other two plantations were outside the park, but nearby. The gravel pit and old pasture were inside the park.

Sampling Methods

Pitfall traps (transects)

In June 1995, 20 pitfall traps were set up in each of the 10 study sites at 10-m intervals along a 200-m

TABLE 1. Comparison of amphibian species sampled using each method within 10 sites in 1995 and 1996.

Species	Pitfall transects	Pitfall arrays	Quadrat searches	Time-constrained searches
Ambystoma maculatum	X	X	X	
Ambystoma laterale		X		
Plethodon cinereus		X	X	X
Notophthalmus viridescens	X	X		
Bufo americanus	X	X		
Pseudacris crucifer	X	X		
Rana clamitans	X	X		
Rana palustris	X	X		
Rana sylvatica	X	X	X	X
Total species	7	9	3	2

transect. The traps were 4L or 6L (both diameter 20 cm) plastic buckets (13 cm or 19 cm deep, respectively), placed in the ground with the opening flush with the surface. Each trap was covered by a 40 cm × 40 cm piece of plywood, raised approximately 5 cm above the surface to prevent rain from entering, to slow evaporation, and to help attract amphibians. Damp moss and/or leaf litter were placed in the traps as shelter. Whenever visited, the traps were moistened if dry, or baled if excess water was present.

The traps were operational from late June - early July 1995 (depending on the site) until the end of October. The traps were re-opened in May 1996, and closed after the first week of November. The traps were checked every 3-15 days, depending on whether many amphibians were moving at the time. Amphibians caught were identified to species, measured for length, and released more than 40 m from the trap.

Pitfall traps (closed arrays)

In May 1996, two closed pitfall arrays were set up at each site. Each array consisted of three 30-cm-tall and 5-m-long drift fences, made of 6 mil plastic sheeting and arranged in a Y-formation, with three pitfall traps in the center of the array and one at each of the three Y-ends (modified from Corn 1994). The plastic sheeting was embedded about 5 cm into the ground and supported erect by stapling to wooden posts.

The arrays were operational from May 1996 and were checked for amphibians at the same time as the transects at the site, with data recorded in the same manner.

Time-constrained searches

Time-constrained searches involve examining habitats for amphibians for a fixed period of time (Campbell and Christman 1982). Two time-constrained searches were conducted at each site in 1996, during or immediately after rain, when habitats were moist. Two people searched for amphibians in moss, leaf litter, coarse woody debris, and under rocks for a fixed time of one hour. The sampling was intense, with rotten logs torn apart and leaf litter searched. The area sampled varied among the sites depending on the abundance of critical microhabitat. Amphibians were measured, recorded to species, and their specific microhabitat noted. Search time was adjusted for the handling and measuring of amphibians.

Quadrat searches

Five quadrat searches were conducted per site during the 1996 field season (modified from Jaeger and Inger 1994). A search consisted of two 5 m × 5 m quadrats, each surveyed by one person, who examined leaf litter, moss, and coarse woody debris, and looked under rocks. Searches were conducted any time of the day in the fall and on overcast days in the summer, but only in the early morning on sunny, summer days. Quadrats were located using a random procedure, were well-spaced from each other, and any amphibians found were measured (length) and recorded to species, and their specific microhabitat recorded.

Data analysis

For transects and arrays, relative abundance was calculated as the number of amphibians per 100 trap-days, and species richness as the number of species per 100 trap-days. Each pit-fall trap in the arrays was treated as a sampling unit. The number of amphibians per 250 m^2 was used as the measurement of relative abundance for quadrat searches, and the number per hour for the time-constrained searches. Wilcoxon signed-rank tests were used to determine which method sampled the greatest species richness or abundance of amphibians ($p \leq 0.05$).

Results

Pitfall transects and pitfall arrays sampled the most species (Table 1), with arrays being most effective in terms of sampling the greatest species richness or abundance of amphibians (Tables 2 and 3). Pitfall arrays caught nine species, whereas pitfall transects caught seven. The quadrat and time-constrained searches sampled only a few species (Table 1). The differences in abundance and species rich-

TABLE 2. Relative abundance and species richness of amphibians caught in pitfall transects and arrays. Data are in numbers of captures per 100 trap-days, during spring, summer, and fall of 1996.

	Relative abundance		Species richness	
Site	Pitfall transect	Pitfall array	Pitfall transect	Pitfall array
1	0.24	4.54	0.03	0.34
2	0.00	0.22	0.00	0.15
3	0.00	0.85	0.00	0.25
4	0.47	5.23	0.06	0.15
5	0.00	0.93	0.00	0.21
6	0.00	0.19	0.00	0.13
7	0.12	0.63	0.06	0.21
8	0.04	0.44	0.04	0.25
9	0.91	4.73	0.18	0.42
10	0.00	0.05	0.00	0.05

ness of amphibians caught in pitfall arrays was significantly greater than in pitfall transects (both $p \leq 0.005$, Wilcoxon signed-rank test). Overall, sites 1, 4 and 5 had the greatest abundance of amphibians, whereas site 6 (old pasture) had the lowest (Table 2). Although the quadrat searches discovered only three amphibian species, *P. cinereus* was caught more frequently than by other methods. This species climbs well, and was not effectively retained in pitfall traps. The time-constrained searches did not uncover any species that were not found using another method (Table 2). They also were more destructive to habitat than quadrat searches, because the area searched was greater.

The pitfall arrays and transects trapped more than just amphibians. Shrews were found dead in these traps, and less commonly mice or voles. Because shrews will eat amphibians, traps containing these animals were not used in the data analysis. Because shrew-catching was frequent (occurring at least once each time most sites were checked), with as many as five shrews in one trap, it may have reduced the local shrew population. Pitfall arrays caught more small mammals than pitfall transects. Twenty-two percent of pitfalls were disturbed by shrews or other agents (in 1996).

Discussion

Campbell and Christman (1982) found that pitfall arrays captured more species and numbers of individuals, when compared with quadrat and time-constrained searches of similar effort. Other studies also have found that pitfalls with drift fences are better than other sampling methods (Bennett et al. 1980; Vogt and Hine 1982; Degraaf and Rudis 1990). Our study has confirmed that pitfall arrays are an efficient method to sample amphibian populations in terrestrial habitats (i.e., in terms of sampling the greatest species richness and abundance).

Pitfall arrays sampled most of the amphibians occurring in the terrestrial habitats in our study area. Because they incorporate drift fencing, pitfall arrays are more efficient than pitfall transects, catching more species (9 compared to 7 in the transects) and a greater abundance of amphibians (mean 17.8 per 100 trap-days compared to 1.8 in the transects; Tables 2 and 3). Consequently, pitfall arrays are clearly the method of choice for monitoring most terrestrial amphibians.

An evaluation of pitfall trapping by Bury and Corn (1987) found that an open array with pitfall and funnel traps and drift fence of 5 m length was better than pitfall arrays without drift fencing, pitfall arrays with short drift fences, or funnel-trap arrays with short drift fences. The pitfall arrays used in our study were similar to those of Bury and Corn, except that our arrays were closed and funnel traps were not used. Bury and Corn (1987) noted that their funnel traps added only a few individuals to their arrays, and were much less effective at capturing some amphibian species than open pitfall traps.

Quadrat searches and time-constrained searches are a relatively active method of sampling. Time-constrained searches disturbed more habitat and did not provide enough data to establish an index of the

TABLE 3. Index of relative amphibian abundance (number per/100 trap-days), as sampled by pitfall arrays in 1996.

	Sites									
Species	1	2	3	4	5	6	7	8	9	10
Ambystoma maculatum	3.46	-	0.42	1.81	0.31	0.13	0.21	0.19	3.70	0.0
Ambystoma laterale	-	-	-	-	-	-	-	-	0.12	-
Notophthalmus viridescens	0.68	0.07	0.25	3.22	0.05	-	0.35	0.06	0.24	-
Plethodon cinereus	-	0.15	0.17	-	0.51	-	-	-	-	-
Bufo americanus	-	-	-	-	0.05	0.06	0.07	-	0.30	-
Pseudacris crucifer	-	-	-	-	-	-	-	-	0.06	-
Rana sp.	-	-	-	0.05	-	-	-	-	-	-
Rana clamitans	0.07	-	-	-	-	-	-	0.12	0.12	-
Rana palustris	0.14	-	-	0.15	-	-	-	-	0.18	-
Rana sylvatica	0.20	-	-	-	-	-	-	0.06	-	-
Total trap-days	1475	1361	1179	1989	1943	1589	1436	1608	1650	194

abundance of amphibians. Campbell and Christman (1982), however, found that time-constrained searches were the most efficient sampling method in forest habitat in Ocala National Forest, Florida, when compared with pitfall arrays and quadrat searches. Their result was largely due to the poor ability of pitfalls to sample certain species, particularly tree-frogs. Although we do not recommend quadrat sampling for general monitoring purposes in our study region, this method was the most effective one for sampling *Plethodon cinereus* (Red-backed Salamander), which is not effectively retained in pitfall traps because of its climbing ability. Therefore, in habitats containing *Plethodon cinereus*, quadrat searches should be used in addition to pitfall-array sampling for other species (artifical cover substrates, such as wooden boards, may also sample *P. cinereus* well; Fellers and Drost 1994).

Sampling also can be done more efficiently if it is restricted to seasonally active or migratory periods. We observed highly seasonal activity of the most abundant species in our study; *Ambystoma maculatum* (Yellow-spotted Salamander) and *N. viridescens* (Spotted Newt) (Adams 1997). If trapping were done only during active periods, it would save time, effort, and prevent many deaths of small mammals. Because amphibian migrations vary among years, regions, and species, the sampling could begin just before the usual breeding time of the earliest species, and end when captures decline significantly. A similar sampling strategy could be used in the late summer – autumn period, if movements of juveniles away from breeding ponds are being monitored.

Literature Cited

Adams, J. D. 1997. Amphibian abundance and diversity in ten terrestrial habitats within and in the vicinity of Fundy National Park, New Brunswick. M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

Bennett, S. H., J. W. Gibbons, and **J. Glanville.** 1980. Terrestrial activity, abundance and diversity of amphibians in differently managed forest types. American Midland Naturalist 103: 412–416.

Bishop, C., D. Bradford, G. Casper, S. Corn, S. Droege, G. Fellers, P. Geissler, D. M. Green, R. Heyer, M. Lannoo, D. Larson, D. Johnson, R. McDiarmid, J. Sauer, B. Shaffer, H. Whiteman, and **H. Wilbur.** 1995. A proposed North American monitoring program. Canadian Association of Herpetololgists Bulletin 9: 6–13.

Blaustein, A. R., and **D. B. Wake.** 1990. Declining amphibian populations: A global phenomenon? Trends in Ecology and Evolution 5: 203–204.

Bury, R. B., and **P. S. Corn.** 1987. Evaluation of pitfall trapping in northwestern forests: trap arrays with drift fences. Journal of Wildlife Management 51: 112–119.

Campbell, H. W., and **S. P. Christman.** 1982. Field techniques for herpetofaunal community analysis. Pages 193–200 *in* Herpetological Communities. *Edited by* N. J. Scott, Jr. U. S. Fish and Wildlife Service, Wildlife Research Report 13.

Cooper, L., and **D. Clay.** 1994. An historical review of logging and river driving in Fundy National Park. Research Notes of Fundy National Park, Number 94-05. Parks Canada, Alma, New Brunswick.

Corn, P. S. 1994. Standard techniques for inventory and monitoring (Straight-line drift fences and pitfall traps). Pages 109–118 *in* Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. *Edited by* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. Smithsonian Institution Press, Washington. D.C.

Degraaf, R. M., and **D. D Rudis.** 1990. Herpetofaunal species composition and relative abundance among three New England forest types. Forest Ecology and Management 32: 155–165.

Fellers, G. M., and **C. A. Drost.** 1994. Sampling with artificial cover. Pages 146–150 *in* Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. *Edited by* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. Smithsonian Institution Press, Washington. D.C.

Freedman, B., S. Woodley, and **G. Forbes.** 1996. The Greater Fundy Ecosystem; Planning for an ecologically sustainable landscape. Pages 114–118 *in* Protected Areas in Our Modern World. *Edited by* N. Munro. IUCN World Conservation Congress, Montreal, Quebec.

Jaeger, R. G., and **R. F. Inger.** 1994. Standard techniques for inventory and monitoring (Quadrat sampling). Pages 97–102 *in* Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. *Edited by* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. Smithsonian Institution Press, Washington, D.C.

McAlpine, D. F. 1992. The status of New Brunswick amphibian populations. Pages 26–29 *in* Declines in Canadian Amphibian Populations: Designing a National Monitoring Strategy, *Edited by* C. A. Bishop and K. E. Pettit. Environment Canada. Occasional Paper Number 76, Burlington, Ontario.

Rabb, G. 1990. Declining amphibian populations. Species 13–14: 33–34.

Vogt, R. C., and **R. L. Hine.** 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. Pages 201–217 *in* Herpetological Communities. *Edited by* N. J. Scott, Jr. U. S. Fish and Wildlife Service, Wildlife Research Report 13.

Woodley, S., G. Forbes, and **A. Skibicky.** *Editors.* 1998. State of the Greater Fundy ecosystem. Greater Fundy Ecosystem Research Group, University of New Brunswick, Fredericton, New Brunswick.

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Spawning and Reproductive Biology of the Greater Redhorse, *Moxostoma valenciennesi*, in the Grand River, Ontario

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Cooke, Steven J., and Christopher M. Bunt. 1999. Spawning and reproductive biology of the Greater Redhorse, *Moxostoma valenciennesi*, in the Grand River, Ontario. Canadian Field-Naturalist 113(3): 497–502.

Reproductive ecology of the Greater Redhorse, *Moxostoma valenciennesi*, was studied in the middle reaches of the Grand River, Ontario, from 1995 to 1998. Upstream migration to a weir with two fishways was observed during early spring. Spawning began in late May, when water temperatures were above 13°C, and lasted for up to 14 days, except in 1998, when spawning began in early May and only lasted five days. Spawning occurred in shallow riffle areas comprised of pebble, gravel and cobble. Videographic observations indicated that males usually remained on or near spawning riffles, while females were either attracted by the presence of, or conspicuous behaviour of males. Rapid bursts of snout and lip vibrations were observed in males for up to 5.7 seconds. Vibrations from one male triggered other males to follow suit. When females were present, male snout vibrations usually preceded spasmodic spawning activity among one or two females and up to seven males. Males rolled over one another and the centrally located female, while dorsal and caudal fins vibrated and broke the water surface for up to 10 seconds. Male and female fish were observed to consume eggs of conspecifics. The youngest fish captured from spawning areas were a five year old male and six year old female. Fecundity ranged from 32 000 to 72 000 eggs per female for seven fish, that were between 558 and 610 mm.

Key Words: Greater Redhorse, *Moxostoma valenciennesi*, life history, behaviour, videography, Ontario.

Greater Redhorse, *Moxostoma valenciennesi* Jordan 1886, are considered generally uncommon or rare with possibly disjunct distributions within their general range (Jenkins and Jenkins 1980; Lee et al. 1980). Many conventional creel studies and stream surveys have likely failed to detect the presence of individual redhorse species due to problems with identification and the typical clumping of these fish into the category of suckers or coarse fish. Greater Redhorse are known to inhabit rivers and lakes within the Great Lakes basin, as well as the Ohio River, the upper Mississippi River, and the north basins of the Red River (Kay et al. 1994). Existing reports of spawning behaviour of Greater Redhorse are anecdotal or emanate from visual observations recorded from the Thousand Islands Region of the St. Lawrence River during the early 1970s (Jenkins and Jenkins 1980).

To date, there are no reported descriptions of Greater Redhorse spawning behaviour in smaller streams and river systems. Scott and Crossman (1973) suggested that Greater Redhorse spawn between May and early July in rapidly flowing streams, although they acknowledged that less is known about this species than any other congener.

Spawning by Greater Redhorse has been reported to occur in streams with moderate to swift current at depths of approximately 0.5–1 m (Jenkins and Jenkins 1980). Those authors reported spawning activity in runs with a bed of sand, gravel, and small rubble; however, egg deposition usually occurred over gravel. Other reports suggested that Greater Redhorse probably spawned in river channels and rapids, where eggs were deposited among boulders in water about 3 m deep (Goodyear et al. 1982), although this report is lacking in any specific accounts. The only report of fecundity and sexual maturity was by Mongeau et al. (1992) from a study in Quebec.

The aim of our study was to elucidate the reproductive biology of the Greater Redhorse in the Grand River, Ontario. Visual observations and videography were used to examine spawning behaviour, migratory tendencies, and habitat use. Fecundity was also calculated.

Study Area

The Grand River is a large tributary of Lake Erie located in southwestern Ontario. A detailed description of the conditions of the middle reaches of the Grand River and the study site are presented in Bunt et al. (1998). Greater Redhorse are becoming regarded for their sporting quality (Jenkins and Burkhead 1993), making them worthy targets for anglers during the spring in the Grand River (Steven Cooke, unpublished data), and likely elsewhere. Greater Redhorse were observed to spawn in a 1 km long study site which extended downstream from the Mannheim Weir (43° 25′ N, 80° 25′ W). Qualitative observations were also made along a 16 km reach downstream of the main study site, to Parkhill Dam in Cambridge.

Methods

Reproduction by Greater Redhorse was studied during the springs of 1995 to 1998. As water temperature increased after breakup, the river was monitored twice daily by observers on the banks to document the initiation and cessation of spawning. Fish were only observed to spawn on riffles in the Grand River, so the majority of the sampling effort was directed to these areas. In 1995 and 1996, visual observations were made from river banks. Observers crouched among riparian vegetation and used polarized glasses during the day and small hand-held lights after dusk. When possible, fish were sexed based on the presence of conspicuous caudal and anal fin tubercles. During our extensive field sampling (1995–1998), we observed very few species with similar morphology or colouration which could be misidentified as Greater Redhorse. River Redhorse, *Moxostoma carinatum*, were never collected or observed and Shorthead Redhorse, *Moxostoma macrolepidotum*, were only collected in very limited numbers in 1995 (Chris Bunt, unpublished data). In 1997 and 1998, underwater videography was used to obtain detailed observations of the Greater Redhorse spawning act. A small black and white pin-hole camera housed in black PVC tubing (6 cm diameter, 120 cm long) was positioned to face downstream in a riffle that was used by actively spawning Greater Redhorse on 30 May 1997. The inconspicuous camera housing was anchored with small rocks and did not affect flow conditions over the riffle. Greater Redhorse returned within minutes of positioning the camera in the riffle and resumed what was later determined to be normal spawning behaviour. Similar observations were collected on 5 May 1998 using a small (8 cm diameter, 20 cm long) colour underwater camera. Field of view for both cameras was determined to be 1.13 m^2. Further qualitative observations were recorded by drifting downstream while Greater Redhorse spawned during 1995, 1996 and 1997.

Midday water temperature (12:00 h) was monitored throughout the reproductive period. Discharge information was remotely collected at a station 6 km downstream from the most upstream end of the study site. No major tributaries enter the Grand River between the study site and the flow gauging station. Data were tested for normality using a Lilliefors test (SYSTAT 1992) and were then examined for homogeneity of variance using an F-test (Sokal and Rohlf 1995). Data were considered normal so a model one fixed-effect, one way ANOVA was used to test the null hypothesis of no difference among temperatures or discharge during spawning among each of the four years. The Tukey-Kraemer HSD test (Day and Quinn 1989) was used to examine differences among means. All means reported are ± 1 SE and tests were determined significant at $\alpha = 0.05$.

Throughout the spring in all years, gill-netting, seining, and angling were carried out in a variety of runs, pools and backwaters within the study area. Spawning colours and tuberculation patterns were carefully documented and during 1997, ovaries were removed from randomly selected ripe females collected within two weeks prior to the initiation of spawning. Eggs were counted using the gravimetric method (McGregor 1922). Scales were removed as described by Meyer (1962), cleaned, pressed between glass slides and aged on a microfiche projector.

We surveyed the riffles where spawning activity was observed during 1997 at 128 locations. A 100 cm^2 quadrat was randomly distributed within riffles where spawning was observed. Depth was measured with a calibrated rod to the nearest cm in the center of the quadrat. Surface and bottom velocities were recorded as 10 s averages using a Sigma PVM velocity meter (± 1 $cm \cdot s^{-1}$). Substrate was described using a modified Wentworth Scale (boulder > 256 mm; cobble 64–256 mm; pebble 16–64 mm; gravel 2–16 mm; sand 0.0625–2 mm; silt < 0.0625 mm) [Cummins 1962] and was grouped into a complex based upon the two dominant substrate types within the quadrat. Embeddedness of substrate was categorized as completely embedded, 3/4 embedded, 1/2 embedded, 1/4 embedded and unembedded (Crouse et al. 1981). The percentage of substrate covered by *Cladophora* spp. was also noted.

Results and Discussion

Morphology

When observed out of water, the sides of female and male Greater Redhorse were yellow-gold, dorsal surfaces were olive coloured and ventral surfaces were white. The dorsal and caudal fins were bright red, becoming orange distally. Spawning male Greater Redhorse developed large white tubercles on the anal fin, up to 5 mm in basal diameter. Both caudal fin lobes had tubercles, which tended to be smaller than those on the anal fin. Some males developed fine tubercles on the lower caudal fin and on the snout. Colouration was relatively consistent, but the degree of tuberculation among males was highly variable. Female Greater Redhorse were nontuberculated and usually larger than males. Males handled during spawning tended to lose their tuberculated scales easily. A lateral stripe was not clearly evident on Greater Redhorse as has been observed for other members of the genus (Bob Jenkins, Roanoke College, personal communication).

Timing and Conditions

Spawning events began when mid-day water temperatures rose above 13°C, at which time river levels had fallen below the spring peak. In 1995, spawning was first observed on 20 May when mid-day water temperature was 13.4°C (Figure 1). In 1996 and 1997, spawning was not observed until 26 May, when water temperatures were 13.3°C and 13.7°C, respectively. Despite spawning beginning at similar temperatures in these two years, the mean tempera-

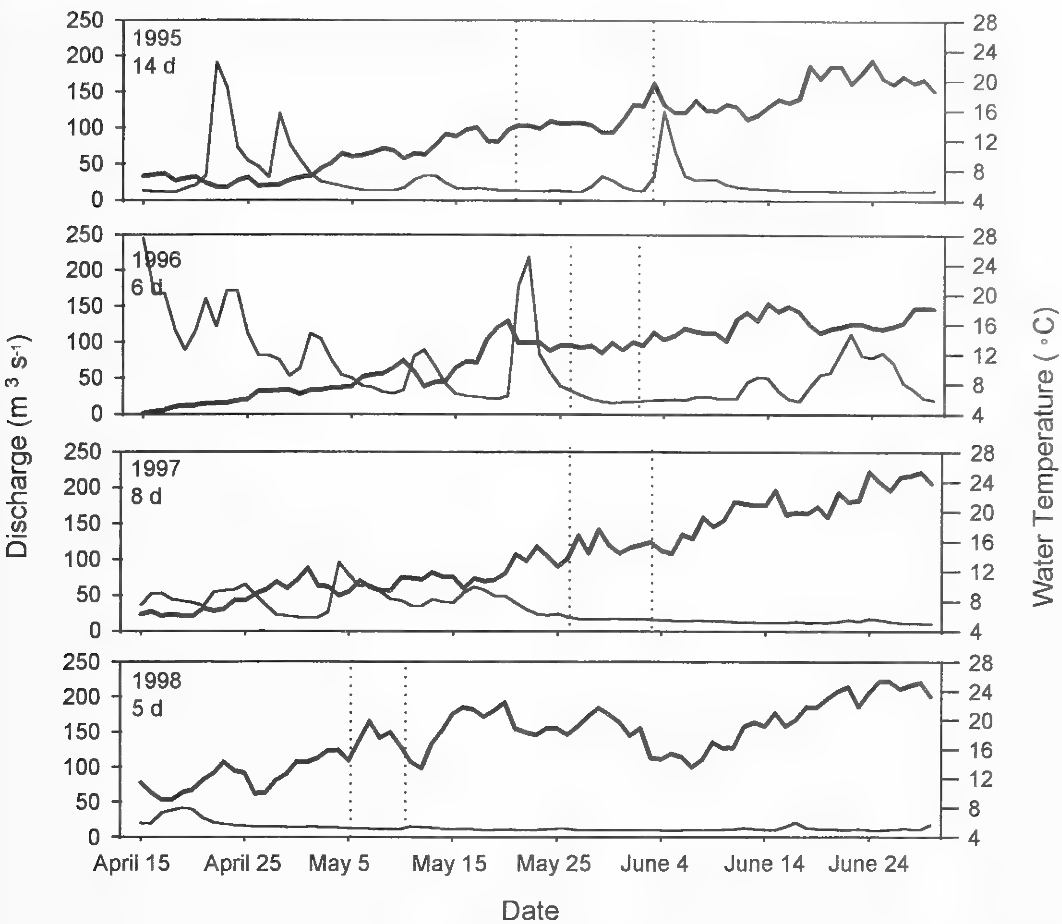

FIGURE 1. Trends in mid-day (12:00 h) water temperature (°C) (thick line) and mean daily discharge ($m^3 s^{-1}$) (thin line) from 15 April to 30 June, 1995-1998. Periods of Greater Redhorse spawning activity are indicated by the area between the dashed vertical lines for each year. The duration of spawning is indicated in the top left corner of the figures.

tures during the spawning period were significantly higher in 1997 ($p<0.05$). During 1998, spawning began on 5 May, at a temperature of 14.5°C. The mean mid-day water temperature (17.5 ± 0.9°C) for the 1998 spawning period was higher than all other years ($p<0.05$).

Individuals were observed to spawn on riffles for 14 d in 1995, at water temperatures ranging from 13.0 to 19.6°C. Spawning was apparently interrupted when discharge increased from 13.2 to over 33.8 $m^3 \bullet s^{-1}$, although it is also possible that the termination of spawning at this time was simply coincidental. Spawning was observed for only 6 days in 1996 and 8 days in 1997. Prior to the initiation of spawning in 1996 and 1997, discharge was highly variable, although temperatures were within the range observed previously. Mid-day water temperature during spawning ranged from 12.2 to 13.6°C in 1996 and 13.7 to 17.6°C in 1997. In 1998, spawning only lasted for 5 days with mid-day temperatures ranging from 14.5 to 19.9°C during which time discharge conditions were stable (12.6 ± 0.24 $m^3 \bullet s^{-1}$). No significant differences in mean discharge were observed among each of the four years ($p>0.05$).

The environmental cues that regulate the initiation of spawning by *Moxostoma* spp. are largely unknown, but seasonality, temperature, photoperiod, and stream discharge are reported to be contributing factors (Kwak and Skelly 1992). Spawning in the Thousand Islands region of the St. Lawrence River occurred during late June to early July, when water temperatures were 16 to 19°C (Jenkins and Jenkins 1980). Although these dates appear late for catostomid spawning, this reach of the St. Lawrence River warms relatively slowly (Jenkins and Jenkins 1980).

Evidence from the Grand River suggests that Greater Redhorse spawning was triggered by a combination of low, stable discharge following spring freshets and water temperatures above 13°C. By the end of the spawning period, most fish were spent, although one ripe male (553 mm TL) was captured 9 days after the last spawning events were recorded in 1996. In 1995, fish that had not completed spawning before discharges increased, and remained ripe, were not observed to spawn when water levels receded. The exceptionally warm and dry spring in 1998 may have reduced spawning duration. Flows were stable throughout this period suggesting that temperature was the final variable influencing the initiation and duration of spawning.

Individuals most actively spawned during sunny afternoons; however, some activity was recorded when it was overcast and raining. Greater Redhorse also spawned after sunset, sometimes as late as midnight. Jenkins and Jenkins (1980) also observed night spawning by Greater Redhorse.

Migrations and Fishway Use

Mature Greater Redhorse swam upstream during early spring in the Grand River. Upstream movements to the Mannheim Weir were observed each year. However, Greater Redhorse were rarely successful at ascending the Denil fishways at the weir. Between 1995 and 1997, only five Greater Redhorse were collected in fishway traps, and three were caught on the same day (20 May 1995) in the east fishway, at a water velocity of 0.56 m•s^{-1} and a water temperature of 14.1°C. Just prior to initiation of spawning, individuals actively explored the region immediately below the weir before returning to riffle areas located further downstream.

Habitat Use

Between 15 May and 25 May 1997, prior to spawning, Greater Redhorse were captured in runs and pools below spawning riffles. Up to 15 Greater Redhorse were observed in aggregations with Common Carp, *Cyprinus carpio*. Smallmouth Bass, *Micropterus dolomieu*, Golden Redhorse, *Moxostoma erythrurum*, and Northern Pike, *Esox lucius*, were also collected in the prespawn pools occupied by Greater Redhorse. Greater Redhorse were not observed feeding but broke the water surface and porpoised frequently in the downstream pools prior to the initiation of spawning; a behaviour observed during the spawning period by Jenkins and Jenkins (1980).

Spawning occurred along edges and midstream areas of riffles of apparent similar morphometry. Riffle depths ranged from 10 to 63 cm (mean 34.4 ± 1.0 cm), surface and bottom velocities varied and ranged from 3.8 to 116.9 cm•s^{-1} (mean 38.21 ± 2.67 cm•s^{-1}) and 4.1 to 87.1 cm•s^{-1} (mean 29.02 ± 1.86 cm•s^{-1}), respectively. Pebble and cobble (59%), and pebble and gravel (30%) were the most commonly used substrate types. Substrate was relatively unembedded and provided large interstitial spaces for egg deposition. Aquatic vegetation in the Grand River during spawning was mostly composed of sparse *Cladophora* spp. However, Greater Redhorse spawning riffles supported large amounts of *Myriophyllum spicatum* and *Potomogeton pectinatus* by early July. Greater Redhorse were observed to use almost every shallow riffle (ca.<60 cm deep) in a 17 km reach between the Mannheim Weir and the Parkhill Dam.

Other species observed with spawning Greater Redhorse were Common Shiner, *Luxilus cornutus*, Striped Shiner *Luxilus chrysocephalus*, Northern Hog Sucker, *Hypentelium nigricans*, White Sucker, *Catostomus commersoni*, and Iowa Darter, *Etheostoma exile*. Carp spawned at similar times, but were seen only in the deeper (i.e., >60 cm) tails of riffles. Between Greater Redhorse spawning events, Common and Striped shiners were observed to spawn on the same riffles, in areas where Greater Redhorse also spawned.

Behaviour

From shore, Greater Redhorse were observed to spawn in groups with between two and seven males and one or two females. One observer counted an aggregation of over 100 Greater Redhorse on a 45 m^2 riffle at one time. Spawning was most intense during the first three days of the spawning period, when spawning events occurred every 1 to 3 s in a 100 m section, 800 m downstream from the Mannheim Weir. During the latter part of the spawning period, and after dark, spawning was less frequent (e.g., every 1 to 2 min). During 1998, spawning was sustained at a consistent level of high intensity for the entire 5 d that spawning was observed. Although we observed hundreds of spawning events from shore, it was more difficult to accurately identify the number and sex of participants from our low vantage-point. Greater Redhorse in the Grand River were particularly wary, making visual observations from shore somewhat difficult.

Underwater videographic observations yielded detailed images showing that males usually remained stationary on or near spawning areas. When an individual female approached from downstream, two, or more commonly three males, attempted to initiate spawning (Table 1). Male Greater Redhorse rapidly vibrated their rostrums and lips prior to and during spawning; a behaviour that was observed to last for up to 5.7 s. Gentle nudging behaviours were often observed between males when no females were present on the spawning riffle, as also observed by Jenkins and Jenkins (1980). This nudging behaviour may be widespread among suckers (Page and Johnston 1990).

During the spawning act, dorsal and caudal fins vibrated vigorously, and broke the water surface in most instances. Males rolled over one another and the centrally located female, while gametes were released. Similar rolling behaviour was observed for Shorthead Redhorse by Burr and Morris (1977).

TABLE 1. Summary of spawning behaviour based on underwater videographic observations. Camera was deployed for a total of 6.5 h between 15:30 and 18:30 on 30 May 1997 and 16:00 and 20:00 on 5 May 1998.

Date	Spawning Act Participants Male	Spawning Act Participants Female	Duration (s)	Time Between Acts (min:s)	Snout Vibrations Participants	Snout Vibrations Sex
30 May 1997	3	1	3.5	a	1	m
30 May 1997	2	1	4.7	01:55	1	m
30 May 1997	3	1	4.5	04:50	3	m
30 May 1997	3	1	4.1	00:01	3	m
30 May 1997	b	b	2.6	20:00	b	b
30 May 1997	3	1	4.0	18:10	2	m
30 May 1997	3	1	6.0	45:30	2	m
30 May 1997	3	1	8.2	19:40	1	m
30 May 1997	3	1	3.4	16:57	2	m
05 May 1998	3	1	1.9	a	1	m
05 May 1998	3	1	2.6	55:12	3	m
05 May 1998	c	c	3.7	24:15	1	m
05 May 1998	3	1	7.6	37:35	2	m

[a]First event following camera placement
[b]Details obscured
[c]At least one male and female observed

Spawning events usually involved males on either side of a female while a satellite male attempted, sometimes successfully, to displace one or both spawning males. The mean duration of the spawning act was 4.4 ± 0.5 s and the mean time between spawning acts within the camera viewing area was 22.2 ± 5.3 min (Table 1). Spawning act durations reported here are similar to those reported by Jenkins and Jenkins (1980).

Although Greater Redhorse do not construct nests prior to spawning (Jenkins and Jenkins 1980), areas of egg deposition eventually became conspicuous following repeated spawning events. Spawning activity cleared finer substrates, created unembedded areas, and removed patches of *Cladophora* spp. The spawning sites appeared lighter in colour and remained evident for up to two weeks following the cessation of spawning. Greater Redhorse eggs were found in the interstitial spaces of the substrate, to a depth of 25 cm. Kwak and Skelly (1992) were unable to determine if Black Redhorse, *Moxostoma duquesnei*, and Golden Redhorse nests were created prior to spawning, but similar to our findings, they suggested that depressions may be created by agitation during the spawning act.

Between spawning events, males and females moved about the riffle and interacted with other conspecifics clumped in aggregations. In some cases, fish rested motionless and maintained positions using only pectoral fins. Lundberg and Marsh (1976) described two behaviours referred to as "fin-standing" and "fin-appression" which were observed in captive Silver Redhorse, *Moxostoma anisurum* and Northern Hog Sucker. Videographic observations of Greater Redhorse between spawning events indicated that pectoral fins were used in a similar manner. Greater Redhorse exhibited fin-standing while in areas of lower velocity (e.g., margins of the riffle) and fin appression while in faster regions of the riffle. Fish were usually oriented upstream, and movements were usually directed laterally or upstream.

After Greater Redhorse reached the head of spawning riffles, and the end of suitable spawning habitat, they moved into adjacent runs and fell back to the tail of the riffle before resuming upstream spawning movements. Some fish were individually identifiable by distinct markings, torn flesh or the presence of fungal lesions. Although it is unknown whether fish spawned on a multiple of riffles, our evidence suggests that individual fish occupied riffles within one general area until they were spent or until spawning was halted by high discharge or low temperature. The territoriality observed during Golden Redhorse spawning (see Kwak and Skelly 1992) was not observed among Greater Redhorse. No fish defended territories, and even during spawning, no fish appeared to be dominant.

Male and female Greater Redhorse consumed eggs released by other fish and gametes from spawning events in which they participated as observed on video. Diet analysis of Greater Redhorse confirmed that egg-like material (i.e., yolk) was a component of stomach contents collected during spawning and was of sufficient quantity to likely rule out accidental ingestion. Intraspecific egg consumption among *Moxostoma* spp., has not been previously documented. No interspecific egg predation was observed, unlike previous reports (Jenkins and Jenkins 1980).

Fecundity and Maturity

The earliest age of maturity in the Grand River was 5 years for males and 6 years for females. The oldest fish observed spawning were a 13 year-old male and an 11 year-old female. Mongeau et al. (1992) reported that external sexual dimorphism in the Richelieu River, Quebec, was not evident until age 8 and that males and females did not spawn until age 9. Jenkins (1970) suggested that maturity, based upon tuberculation, occured in males between 380 and 540 mm (SL) and males probably matured at ages 5 and 6. In the Grand River, immature individuals were not found in aggregations with mature individuals before or during spawning. It should be noted that the ages presented here are likely conservative, as use of scales may result in underestimates of age.

Calculations of the number of eggs produced by female Greater Redhorse varied between 31 759 and 71 920 (mean ± 1 SE, 39 554.3 ± 5472.5) for seven fish between 558 and 610 mm TL (Age 6–9). These values are within the range reported for similarly sized Greater Redhorse by Mongeau et al. (1992). They reported fecundity ranging from 25 190–51 430 eggs for 10 females. They also reported that gonadosomatic index values continued to increase into mid-June, when water temperatures were greater than 16°C.

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Literature Cited

Bunt, C. M., S. J. Cooke, and **R. S. McKinley.** 1998. Creation and maintenance of habitat downstream from a weir for the greenside darter *Etheostoma blennioides* — a rare fish in Canada. Environmental Biology of Fishes 51: 297–308.

Burr, B. M., and **M. A. Morris.** 1977. Spawning behaviour of the shorthead redhorse, *Moxostoma macrolepidotum,* in Big Rock Creek, Illinois. Transactions of the American Fisheries Society 106: 80–82.

Crouse, M. R., C. A. Callahan, K. W. Malueg, and **S. E. Dominguez.** 1981. Effects of fine sediment on growth of juvenile coho salmon in laboratory streams. Transactions of the American Fisheries Society 110: 281–286.

Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. American Midland Naturalist 67: 477–504.

Day, R. W., and **G. P. Quinn.** 1989. Comparisons of treatments after an analysis of variance in ecology. Ecological Monographs 59: 433–463.

Goodyear, C. D., T. A. Edsall, D. M. Ormsby Dempsey, G. D. Moss, and **P. E. Polanski.** 1982. Atlas of spawning and nursery areas of Great Lakes fishes. U.S. Fish Wildlife Service. FWS/OBS–82/52, Washington, D.C. 144 pages.

Jenkins, R. E. 1970. Systematic studies of the catostomid fish tribe Moxostomatini. Ph.D. thesis, Cornell University, Ithaca. 799 pages.

Jenkins, R. E., and **N. M. Burkhead.** 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda. 1079 pages.

Jenkins, R. E., and **D. J. Jenkins.** 1980. Reproductive behavior of the greater redhorse, *Moxostoma valenciennesi*, in the Thousand Islands Region. Canadian Field-Naturalist 94: 426–430.

Kay, L. K., R. Wallus, and **B. L. Yeager.** 1994. Reproductive biology and early life history of fishes in the Ohio River drainage. Volume 2: Catastomidae. Tennessee Valley Authority, Chattanooga. 242 pages.

Kwak, T. J., and **T. M. Skelly.** 1992. Spawning habitat, behavior, and morphology as isolating mechanisms of the golden redhorse, *Moxostoma erythrurum*, and the black redhorse, *M. duquesnei*, two syntopic fishes. Environmental Biology of Fishes 34: 127–137.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and **J. R. Stauffer, Jr.** 1980. Atlas of North American freshwater fishes. Publication 1980-12, North Carolina State Museum of Natural History, Raleigh. 854 pages.

Lundberg, J. G., and **E. Marsh.** 1976. Evolution and functional anatomy of the pectoral fin rays in cyprinoid fishes, with emphasis on the suckers (family Catostomidae). American Midland Naturalist 96: 332–349.

McGregor, E. A. 1922. Observations on the egg yield of Klamath River king salmon. California Fish and Game 8: 160–164.

Meyer, W. H. 1962. Life history of three species of redhorse (*Moxostoma*) in the Des Moines River, Iowa. Transactions of the American Fisheries Society 91: 412–419.

Mongeau, J. R., P. Dumont, and **L. Cloutier.** 1992. La biologie du suceur cuivré (*Moxostoma hubbsi*) comparée à celle de quatre autres espèces de *Moxostoma* (*M. anisurum, M. carinatum, M. macrolepidotum* et *M. valenciennesi*). Canadian Journal of Zoology 70: 1354–1363.

Page, L. M., and **C. E. Johnston.** 1990. Spawning in the creek chubsucker, *Erimyzon oblongus*, with a review of spawning behavior in suckers (Catostomidae). Environmental Biology of Fishes 27: 265–272.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. 966 pages.

Sokal, R. R., and **F. J. Rohlf.** 1995. Biometery. 3rd edition. W. H. Feeman and Company, New York. 887 pages.

SYSTAT. 1992. Statistics, version 5.2 edition. SYSTAT, Inc., Evanston, Illinois.

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Notes

Bird Blow Flies, *Protocalliphora* (Diptera: Calliphoridae), in Cavity Nests of Birds in the Boreal Forest of Saskatchewan

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The frequency of infestation by larval bird blow flies, *Protocalliphora*, an obligate blood-sucking parasite of nestling birds, in the nests of American Kestrels (*Falco sparverius*) was documented in north-central Saskatchewan. We found no evidence of feeding *Protocalliphora* in 76 intensively monitored nests. Nesting material from 92 nests was searched for puparia after chicks had fledged, and only a single *P. avium* puparium was recovered. We suggest that *Protocalliphora* are not important parasites for nestling kestrels in the boreal forest. Although *Protocalliphora* were also absent in four Boreal Owl (*Aegolius funereus*) nests, we did recover *P. shannoni* from Tree Swallow (*Tachycineta bicolor*) and House Wren (*Troglodytes aedon*) nests. These latter results suggest the absence of *Protocalliphora* in kestrel nests is probably due to species that normally infest kestrels not occurring on our study area, as opposed to the genus as a whole being absent. This study is the first to document *P. avium* in American Kestrel nests, and expands the known range of *P. shannoni*.

Key Words: Bird Blow Flies, *Protocalliphora*, haematophagous parasites, American Kestrel, *Falco sparverius*, Boreal Owl, *Aegolius funereus*, House Wren, *Troglodytes aedon*, Tree Swallow, *Tachycineta bicolor*, Saskatchewan.

The genus *Protocalliphora* (Diptera: Calliphoridae) is a Holarctic group whose larvae are obligate haematophagous parasites of nestlings birds (Sabrosky et al. 1989). Larvae of most species are intermittent feeders, living among nest material between blood meals, or occasionally remaining on nestlings (Sabrosky et al. 1989; Bennett and Whitworth 1991). Further information on the life history of *Protocalliphora* can be found elsewhere (Sabrosky et al. 1989; Bennett and Whitworth 1991, 1992; Whitworth and Bennett 1992).

Although most studies have been unable to implicate *Protocalliphora* in the deaths of nestlings (Whitworth 1976; Sabrosky et al. 1989; Rogers et al. 1991; Roby et al. 1992; Wittman and Beason 1992; Miller and Fair 1997; but see Pinkowski 1977; Merino and Potti 1995), Whitworth (1976) speculated that *Protocalliphora* may expedite nestling mortality during periods of food shortage or inclement weather (see also Howe 1992). Furthermore, Roby et al. (1992) found subtle differences in nestling mass of Eastern Bluebirds (*Sialia sialis*) and Tree Swallows (*Tachycineta bicolor*) infested with *Protocalliphora* larvae. Reduced fledging mass in passerines has been associated with lower post-fledging survival (Tinbergen and Boerlijst 1990; Magrath 1991), suggesting the possibility that even small effects of *Protocalliphora* parasitism can have fitness consequences for birds. Moreover, it has been suggested that parent birds may increase their rates of energy expenditure when feeding offspring in infested nests (Johnson and Albrecht 1993).

Avian ecologists have become increasingly aware of the deleterious effects of ectoparasites (see references in Christe et al. 1996), so we sought to examine whether *Protocalliphora* might play a role in the reproductive success of American Kestrels (*Falco sparverius*), a small falcon. As a starting point for our investigation, we documented the degree of *Protocalliphora* parasitism in nests of kestrels in the boreal forest of north-central Saskatchewan. Our initial results prompted us to also investigate, on a limited scale, the degree of *Protocalliphora* infestations in several other species of cavity nesting birds on our study area.

Methods

We studied American Kestrels breeding in nest boxes during 1995 in the boreal forest near Besnard Lake, Saskatchewan (55°N, 106°W). Nest boxes contained a few centimeters of wood shavings, and old nesting material was removed from our nest boxes prior to the breeding season, which may have reduced the prevalence and intensity of some ectoparasite infestations (Møller 1989). Further details of our general methods can be found elsewhere (Bortolotti 1994; Dawson and Bortolotti 1997a).

During the course of routine field work, we visited kestrel nests and inspected each nestling for the presence of actively feeding *Protocalliphora* larvae, or other evidence that chicks were being fed upon by *Protocalliphora*, such as scabs or larval faeces from larvae occupying aural or nasal cavities (see Bortolotti 1985). At this time, we also documented the degree of parasitism by *Carnus hemapterus* (Diptera: Carnidae) (Dawson and Bortolotti 1997b).

We collected nesting material from 90 kestrel nests approximately eight days (range 1 to 21 days) after nestlings fledged. Also, material was collected from two additional kestrel nests when chicks were 11 and 20 days old. All material from nest boxes was carefully placed in paper bags, sealed, and stored in an outdoor shelter. Nesting material was subsequently examined by T. L. W. for the presence of *Protocalliphora* puparia as well as for adult flies that may have emerged after nesting material was collected. In addition, we also examined material from two Boreal Owl (*Aegolius funereus*) nests collected in 1993, and two Boreal Owl, two Tree Swallow, and two House Wren (*Troglodytes aedon*) nests collected in 1996 from nest boxes on our study area.

Results

In total, we inspected 306 individual kestrel chicks from 76 nests a total of 1303 times. Ages at inspection ranged from the day of hatching to 25 days (approximate minimum fledging age; personal observation). We observed dipteran larvae on nestlings at only one nest during the course of the study. During a visit to this nest on 24 June 1995, the smallest nestling, which was less than 24-hours old, had a cavity 6 mm in diameter in its abdominal area where the umbilicus had been attached. Inside this cavity, which appeared to penetrate into the coelom, were at least 7 larvae. The chick was noticeably weak and pale. None of the other four chicks showed evidence of feeding during this visit. The next day, the previously infested chick was gone from the nest, and we assumed it had died and been removed or cannibalized by its parents (see Bortolotti et al. 1991). One other chick in this nest had a 2 mm diameter cavity in its left wing axillae that penetrated into muscle tissue, and another nestling had a similar-sized cavity in its left wing axillae that contained a single larva. This larva was collected and preserved in 70% alcohol. The larva was a second instar, and although even generic identification at this stage of the life cycle is difficult, it did not resemble *P. braueri*, the only *Protocalliphora* known to cause subcutaneous myiasis (Sabrosky et al. 1989). We suspect that the observed larvae in this nest were myiasis-producing scavenger species such as *Phormia regina*. We visited this nest seven additional times during the course of the next 24 days. Larvae were not observed again, and all four remaining nestlings fledged successfully from the nest.

Only a single *Protocalliphora* puparium was found in 92 kestrel nests collected in 1995, and it was identified as *P. avium*. No evidence of *Protocalliphora* infestations were detected in the Boreal Owl nests; however, 60 *P. shannoni* puparia and several emerged adults were found in one Tree Swallow nest, and one House Wren nest had 15 *P. shannoni* puparia. We lack information on whether the uninfested wren and swallow nests successful fledged young or whether they failed early in the nestling period. The condition of the nesting material suggested they did not fledge young. It is generally necessary for nestlings to survive at least 7 to 10 days to allow sufficient time for *Protocalliphora* larvae to reach the third instar stage and pupate, and thus be detectable when nesting material is searched (Bennett and Whitworth 1991).

Discussion

We found little evidence that *Protocalliphora* larvae are common parasites of American Kestrel nestlings in the boreal forest of Saskatchewan. The single puparium encountered in kestrel nests is, to our knowledge, the first report of *P. avium* from American Kestrels. Bortolotti (1985) found all nestling Bald Eagles (*Haliaeetus leucocephalus*) on our study area harbored *P. avium* at some point during their development. *P. avium* is a common species, but is generally found in large open nests in the forest canopy (Sabrosky et al. 1989; Bennett and Whitworth 1992). The presence of *P. avium* in kestrel nests is therefore atypical.

Møller (1989) suggested that removal of old nesting material from nest boxes might reduce levels of some avian ectoparasites. We do not believe this can account for the lack of *Protocalliphora* in our kestrel nests. Previous studies have suggested that parasitism by *Protocalliphora* is not associated with either the presence or absence of old nesting material (Johnson 1996; Rendell and Verbeek 1996) because *Protocalliphora* overwinter as adults, as pupae cannot survive through the winter (Bennett and Whitworth 1991). Adult *Protocalliphora* would certainly have dispersed from the host nest after emergence (Rendell and Verbeek 1996). Moreover, removal of old nesting material may reduce levels of the wasp *Nasonia vitripennis* (Hymenoptera: Pteromalidae), and other pteromalids that attack *Protocalliphora* pupae (Sabrosky et al. 1989).

Although it is tempting to speculate that kestrels are not suitable hosts for *Protocalliphora*, Bennett and Whitworth (1992) reported 33% of kestrel nests in Utah contained *Protocalliphora*, and Balgooyen (1976) suggested up to 25% of nests in the Sierra

Nevada of California can be infested. Biotic or abiotic attributes of our study area also cannot explain the paucity of *Protocalliphora* in kestrel nests. Bortolotti's (1985) previous work, as well as the detection of *P. shannoni* in Tree Swallow and House Wren nests in this study, confirm that *Protocalliphora* exist on our study area. Instead, we suggest that our study area has relatively few *Protocalliphora* species that commonly infest kestrels. Species that are more typically found in kestrel nests, such as *P. sialia* and, to a lesser extent *P. lata* (Bennett and Whitworth 1992), have not been documented in the vicinity of our study area (see Sabrosky et al. 1989), and may therefore not occur on our study area. As the distribution of *Protocalliphora* is very poorly known (Sabrosky et al. 1989), further study is necessary to confirm this.

We conclude that given the low frequency of infestations, *Protocalliphora* are not considered to be a significant factor in the reproductive success of American Kestrels in the boreal forest of Saskatchewan. When subcutaneous myiasis by *Phormia regina* (or *Protocalliphora braueri*) occurs, it is possible that mortality can occur, as we observed for one nestling; however, because of the rarity of this event, we also do not believe that *Phormia* are important parasites for kestrels in the boreal forest. The presence of *P. shannoni* in House Wren and Tree Swallow nests in north-central Saskatchewan expands the known range of this species. Most previous records of *P. shannoni* have come from southeastern Canada and the northeastern United States, plus scattered records from British Columbia, the Yukon, Montana, and Utah (Sabrosky et al. 1989).

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Literature Cited

Balgooyen, T. G. 1976. Behavior and ecology of the American Kestrel (*Falco sparverius* L.) in the Sierra Nevada of California. University of California Publications in Zoology 103: 1–83.

Bennett, G. F., and **T. L. Whitworth.** 1991. Studies on the life history of some species of *Protocalliphora* (Diptera: Calliphoridae). Canadian Journal of Zoology 69: 2048–2058.

Bennett, G. F., and **T. L. Whitworth.** 1992. Host, nest, and ecological relationships of species of *Protocalliphora* (Diptera: Calliphoridae). Canadian Journal of Zoology 70: 51–61.

Bortolotti, G. R. 1985. Frequency of *Protocalliphora avium* (Diptera: Calliphoridae) infestations on Bald Eagles (*Haliaeetus leucocephalus*). Canadian Journal of Zoology 63: 165–168.

Bortolotti, G. R. 1994. Effects of nest-box size on nest-site preference and reproduction in American Kestrels. Journal of Raptor Research 28: 127–133.

Bortolotti, G. R., K. L. Wiebe, and **W. M. Iko.** 1991. Cannibalism of nestling American Kestrels by their parents and siblings. Canadian Journal of Zoology 69: 1447-1453.

Christe, P., H. Richner, and **A. Oppliger.** 1996. Begging, food provisioning, and nestling competition in Great Tit broods infested with ectoparasites. Behavioral Ecology 7: 127–131.

Dawson, R. D., and **G. R. Bortolotti.** 1997a. Variation in hematocrit and total plasma proteins of nestling American Kestrels (*Falco sparverius*) in the wild. Comparative Biochemistry and Physiology 117A: 383–390.

Dawson, R. D., and **G. R. Bortolotti.** 1997b. Ecology of parasitism of nestling American Kestrels by *Carnus hemapterus* (Diptera: Carnidae). Canadian Journal of Zoology 75: 2021–2026.

Howe, F. P. 1992. Effects of *Protocalliphora braueri* (Diptera: Calliphoridae) parasitism and inclement weather on nestling Sage Thrashers. Journal of Wildlife Diseases 28: 141–143.

Johnson, L. S. 1996. Removal of old nesting material from nesting sites of House Wrens: effects on nest-site attractiveness and ectoparasite loads. Journal of Field Ornithology 67: 212–221.

Johnson, L. S., and **D. J. Albrecht.** 1993. Effects of haematophagous ectoparasites on nestling House Wrens, *Troglodytes aedon*: who pays the cost of parasitism? Oikos 66: 255–262.

Magrath, R. D. 1991. Nestling weight and juvenile survival in the Blackbird *Turdus merula*. Journal of Animal Ecology 60: 335–351.

Merino, S., and **J. Potti.** 1995. Mites and blowflies decrease growth and survival in nestling Pied Flycatchers. Oikos 73: 95–103.

Miller, C. K., and **J. M. Fair.** 1997. Effects of blow fly (*Protocalliphora spatulata*: Diptera: Calliphoridae) parasitism on the growth of nestling Savannah Sparrows. Canadian Journal of Zoology 75: 641–644.

Møller, A. P. 1989. Parasites, predators and nest boxes: facts and artefacts in nest box studies of birds? Oikos 56: 421–423.

Pinkowski, B. C. 1977. Blowfly parasitism of Eastern Bluebirds in natural and artificial nest sites. Journal of Wildlife Management 41: 272–276.

Rendell, W. B., and **N. A. M. Verbeek.** 1996. Are avian ectoparasites more numerous in nest boxes with old nest material? Canadian Journal of Zoology 74: 1819–1825.

Roby, D. D., K. L. Brink, and **K. Wittmann.** 1992. Effects of bird blowfly parasitism on Eastern Bluebird and Tree Swallow nestlings. Wilson Bulletin 104: 630–643.

Rogers, C. A., R. J. Robertson, and **B. J. Stutchbury.** 1991. Patterns and effects of parasitism by *Protocal-*

liphora sialia on Tree Swallow nestlings. Pages 123–139 *in* Bird-parasite interactions. *Edited by* J. E. Loye and M. Zuk. Oxford University Press, Oxford, U.K.

Sabrosky, C. W., G. F. Bennett, and **T. L. Whitworth.** 1989. Bird blow flies (*Protocalliphora*) in North America (Diptera: Calliphoridae). Smithsonian Institution Press, Washington, D.C. 312 pages.

Tinbergen, J. M., and **M. C. Boerlijst.** 1990. Nestling weights and survival in individual Great Tits. Journal of Animal Ecology 59: 1113–1127.

Whitworth, T. L. 1976. Host and habitat preferences, life history, pathogenicity and population regulation in species of *Protocalliphora* Hough (Diptera: Calliphoridae). Ph.D. dissertation, Utah State University, Logan.

Whitworth, T. L., and **G. F. Bennett.** 1992. Pathogenicity of larval *Protocalliphora* (Diptera: Calliphoridae) parasitizing nestling birds. Canadian Journal of Zoology 70: 2184–2191.

Wittman, K., and **R. C. Beason.** 1992. The effect of blowfly parasitism on nestling Eastern Bluebird development. Journal of Field Ornithology 63: 286–293.

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Additional Notes on Vegetation of Dry Openings Along the Trent River, Ontario

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Catling, Paul M., and Vivian R. Brownell. 1999. Additional notes on vegetation of dry openings along the Trent River, Ontario. Canadian Field-Naturalist 113(3): 506–509.

Additions and corrections are provided for two tables which accompanied a recently published description and analysis of dry, open, natural habitats along the Trent River in the eastern portion of southern Ontario. The vascular floras of two additional dry open areas near Crowe Bridge and Campbellford are recorded. The former site is on shallow soil over limestone and includes some of the few examples of alvar plant communities that remain undisturbed and relatively rich in native species along the Trent River system. The latter site is an important addition to the relict limestone savannas that provide an indication of the natural vegetation that once characterized much of the Trent River system. It is also of phytogeographic interest and includes a rich native flora and rare species.

Key Words: alvar, savanna, rare species, vegetation, Trent River, eastern Ontario.

Native vegetation of dry openings has been reduced to a small percentage of its original extent in southern Ontario (Catling and Brownell 1995, in press; Catling and Catling 1993; Catling et al. 1992). The remaining habitats are therefore important for consideration for protection and as an indication of the composition of declining natural vegetation in the southern part of the province. The vascular flora

TABLE 1. Corrections and additions to Appendix Table 1 *in* Catling and Catling 1993, which provided a list of vascular plants of dry, natural openings along the Trent River in eastern Ontario.

Species	Notes
Bouteloua curtipendula (Michx.) Torr., Side Oats Grama	delete 1, add 13
Bromus pubescens Willd., Hairy Brome	delete 6, add 1
Cyperus lupulinus (Sprengel) Marcks, Slender Cyperus	add 6 and 7
Linum sulcatum Riddell, Grooved Yellow Flax	delete 11, add 6
Panicum (*Dichanthelium*) *columbianum* Scribner, Panic Grass	add 3
Panicum (*Dichanthelium*) *depauperatum* Muhl., Panic Grass	delete 2, add 8
Panicum (*Dichanthelium*) *perlongum* Nash, Panic Grass	add 12
Potentilla recta L., Rough-fruited Cinquefoil	delete from table since not native
Salix humilis Marshall, Prairie Willow	add 7
Saxifraga virginiensis Michx., Early Saxifrage	delete 11, add 6
Thuja occidentalis L., Eastern White Cedar	delete 3, add 13
Vaccinium angustifolium Aiton, Low Sweet Blueberry	delete 11, add 6
Viola affinis Le Conte, Le Conte's Violet	add 3
Viola fimbriatula Smith, Arrow-leaved Violet	add 12
Vitis riparia Michx., Riverbank Grape	add 14
Zanthoxylum americanum Miller, Prickly-ash	add 2

TABLE 2. Native vascular plants of the Campbellford alvar savanna (1) and Crowe Bridge alvar savanna (2) area. * = provincially rare based on S1-S3 in Oldham (1996*). + = rare in the Lake Ontario Lowlands physiographic region (and all but *Aster ciliolatus* are rare throughout eastern Ontario) based on Cuddy (1991*), Brownell and Blaney (1996*), and personal observations.

Achillea millefolium L., Yarrow, 1, 2
Agrostis scabra Willd., Ticklegrass, 1
Amelanchier alnifolia Nutt. var. *compacta* (Nielson) McKay, Saskatoon-berry, 1, 2
Anemone cylindrica Gray, Long-fruited Anemone, 1, 2
Antennaria neglecta E. Greene, Pussytoes, 1, 2
Antennaria parlinii Fern. ssp. *fallax* (E. Greene) R.J. Bayer & Stebb., Plantain-leaved Pussytoes, 2
Apocynum androsaemifolium L., Spreading Dogbane, 1
Aquilegia canadensis L., Wild Columbine, 1, 2
Arabis divaricarpa A. Nels, Rock-cress, 2
Arabis hirsuta (L.) Scop. var. *pycnocarpa* (Hopkins) Rollins, Rock-cress, 2
Asclepias syriaca L., Common Milkweed, 1
Aster ciliolatus Lindley, aster, 1
Aster cordifolius L., Heart-leaved Aster, 1
Aster lanceolatus Willd. ssp. *lanceolatus*, Tall White Aster, 1
Aster oolentangiensis Riddell, Sky-blue Aster, 1
Aster urophyllus Lindley, Arrow-leaved Aster, 1
+ *Astragalus neglectus* L., Cooper's Milk-vetch, 1
Bromus ciliatus L., Fringed Brome Grass, 1
+ *Calystegia spithamea* (L.) Pursh, Low Bindweed, 1
Campanula rotundifolia L., Harebell, 1, 2
Carex backii Boott, sedge, 1
Carex eburnea Boott, sedge, 1, 2
+ *Carex molesta* Mack. *ex* Bright, sedge, 1, 2
Carex pellita Muhl. (*C. lanuginosa* Michx.), sedge, 1
Carex pensylvanica Lam., sedge, 1, 2
Carex richardsonii R.Br., sedge, 2
Carex siccata Dewey, sedge, 2
Carex umbellata Willd., sedge, 1, 2
Carya ovata (Mill.) K. Koch, Shellbark or Shagbark Hickory, 1
Ceanothus americanus L., New Jersey Tea, 1, 2
Cerastium arvense L., Field Chickweed, 1, 2
Comandra umbellata (L.) Nutt., Bastard Toadflax, 1
Cornus racemosa Lam., Grey Dogwood, 1, 2
Danthonia spicata (L.) R.&S., Poverty Oat Grass, 1, 2
+ *Eleocharis elliptica* Kunth, spike-rush, 1
Eleocharis erythropoda Steud., spike-rush, 1
Elymus hystrix L., Bottle-brush Grass, 1
Elymus trachycaulus (Link) Gould, Slender Wheat Grass, 1, 2
Fragaria virginiana Dcne., Common Strawberry, 1, 2
Fraxinus pennsylvanica Marsh., Green Ash, 1
Galium boreale L., Northern Bedstraw, 1
Galium circaezans Michx., Wild Licorice, 1
Hedeoma hispida Pursh, Mock Pennyroyal, 1
Helianthus divaricatus L., Woodland Sunflower, 1, 2
Helianthus strumosus L., Sunflower, 1
Hepatica americana (DC.) Ker, Round-lobed Hepatica, 1
Juncus dudleyi Wieg., Rush, 1
+ *Juncus secundus* Beauv., Secund Rush, 1
Juniperis virginiana L., Red Cedar, 1, 2
Juniperus communis L. var. *depressa* Pursh, Common Juniper, 1, 2
Lilium philadelphicum L., Wood Lily, 1
Lonicera dioica L., Wild Honeysuckle, 2
Lonicera hirsuta Eat., Hairy Honeysuckle, 1
Minuartia michauxii (Fenzl) Farw., Rock Sandwort, 2
Monarda fistulosa L., Wild Bergamot, 1, 2
Muhlenbergia glomerata (Willd.) Trin., Muhly Grass, 1
+ *Myosotis verna* Nutt., Forget-me-not, 2
Panicum flexile (Gatt.) Scribn., Panic Grass, 2
Panicum (Dichanthelium) implicatum Scribn., Panic Grass, 1, 2
Panicum philadelphicum Trin., Panic Grass, 1, 2

continued

TABLE 2. *(Concluded)*

Penstemon hirsutus (L.) Willd., Beard-tongue, 1
Poa compressa L., Canada Blue Grass, 1, 2
Poa pratensis L., Kentucky Blue Grass, 1, 2
Polygala senega L., Seneca-snakeroot, 1, 2
Potentilla arguta Pursh, Prairie Cinquefoil, 2
Potentilla norvegica L., Rough Cinquefoil, 1
Prunella vulgaris L., Heal-all, 1, 2
Prunus virginiana L., Chokecherry, 1
Pteridium aquilinum (L.) Kuhn var. *latiusculum* (Desv.) Underw., Eastern Bracken, 1
Quercus alba L., White Oak, 1
Quercus macrocarpa Michx., Bur Oak, 1, 2
Quercus muehlenbergii Engelm., Chinquapin Oak, 1
Quercus rubra L., Red Oak, 1, 2
Rhus aromatica Ait., Fragrant Sumac, 1, 2
Rhus radicans L. ssp. *rydbergii* (Sm. *ex* Rydb.) McNeill, Poison Ivy, 1, 2
Rhus typhina L., Staghorn Sumac, 1
Rosa blanda Ait., Wild Rose, 1
Sanicula marilandica L., Black Snakeroot, 1
Saxifraga virginiensis Michx., Early Saxifrage, 2
Schizachne purpurascens (Torr.) Sw., False Melic Grass, 1, 2
Scutellaria parvula Michx., Skullcap, 1, 2
Senecio pauperculus Michaux, Balsam Ragwort, 1
Shepherdia canadensis (L.) Nutt., Soapberry or Buffaloberry, 1, 2
Smilacina racemosa (L.) Desf., False Solomon's-seal, 1
Smilacina stellata (L.) Desf., False Solomon's-seal, 1, 2
Solidago canadensis L., Canada Goldenrod, 1
Solidago juncea Aiton, Early Goldenrod, 1, 2
* *Solidago nemoralis* Aiton ssp. *decemflora* (DC.) Brammall, 1, 2
Sporobolus vaginiflorus (Torr.) Wood var. *inaequalis* Fern., Ensheathed Dropseed, 1
Symphoricarpos albus (L.) Blake var. *albus*, Snowberry, 1, 2
\+ *Taenidia integerrima* (L.) Drude, Yellow Pimpernel, 1
Thalictrum dioicum L., Early Meadow Rue, 1
Thuja occidentalis L., White Cedar, 2
Trichostema brachiatum L., False Pennyroyal, 1, 2
\+ *Verbena stricta* Vent., Hoary Vervain, 1
Veronica peregrina L. var. *peregrina*, Purslane Speedwell, 1
Viburnum rafinesquianum Schultes, Downy Arrow-wood, 1, 2
Viola conspersa Reich., Dog Violet, 2
Viola sororia Willd., Common Blue Violet, 2
Virgulus novae-angliae (L.) Reveal & Keener, New England Aster, 1
Waldsteinia fragarioides (Michx.) Tratt., Barren Strawberry, 1
Zanthoxylum americanum Mill., Prickly-ash, 1, 2

of dry openings along the Trent River is of particular interest in being at or near the eastern limit in North America of extensive prairie, savanna, and limestone barren (alvar) vegetation. Here we provide corrections and additions for a previously published list, as well as a list of the vascular plants of two additional sites not included in the earlier descriptions, thus providing a more complete and current information base for this region.

Corrections

Corrections and additions to Appendix Table 1, which accompanied our earlier description and analysis of dry, open, natural habitats along the Trent River in the eastern portion of southern Ontario (Catling and Catling 1993), are shown in Table 1. The corrections relating to the rare and restricted species Side Oats Grama (*Bouteloua curtipendula* (Michx.) Torr.) and Hairy Wood Brome (*Bromus pubescens* Willd.) are especially notable. The correct UTM for Overlook Prairie is 31C/4 935004 and the correct UTM for Plateau Prairie is 31C/4 938004 (correction to Table 1 in Catling and Catling 1993).

Vascular plants of the Crowe Bridge area

Small, dry openings within alvar savanna at Crowe Bridge (44°22′40″N, 77°45′40″W, UTM 31C/5 805175) include some of the best examples of alvar pavement vegetation along the Trent River system and include a number of plant species that have not been found elsewhere along the river or are rare, such as Hairy Rock-cress (*Arabis hirsuta* (L.) Scop.), Vernal Forget-me-not (*Myosotis verna* Nutt.), Panic Grass (*Panicum flexile* (Gatt.) Scrib.), Early

Saxifrage (*Saxifraga virginiensis* Michx.), and Small Skullcap (*Scutellaria parvula* Michx.) (Table 2).

Vascular plants of the Campbellford Savanna

Alvar savanna may have occurred over an area of 3-5 square km south of Campbellford, and may have been more or less continuous along much of the Trent River in presettlement times (Catling and Catling 1993). The scattered remnants south of Campbellford on both sides of the river (44°16'37"N, 77°48'04"W, UTM 31C/5 764064) are only the fourth site that has been identified in sufficiently good condition to provide an indication of the composition of the alvar savanna flora. The remnants are rich in native species of open sites (Table 2) and include rare species such as Cooper's Milk-vetch (*Astragalus neglectus* L.), Low Bindweed (*Calystegia spithamea* (L.) Pursh), Secund Rush (*Juncus secundus* Beauv.), and Yellow Pimpernel (*Taenidia integerrima* (L.) Drude. The site is also of interest in having southern species such as Chinquapin Oak (*Quercus muehlenbergii* Engelm.) at their northern limit and boreal species such as Lindley's Aster (*Aster ciliolatus* Lindl.) at their southern limit.

Documents Cited (marked * in text)

Brownell, V. R., and **C. S. Blaney.** 1996. Lower Trent Region natural areas. Volume 3: A biological inventory and evaluation of 23 natural areas in the Lower Trent Region. 1995. Lower Trent Region Conservation Authority, Trenton, Ontario. 148 pages.

Cuddy, D. G. 1991. Vascular plants of eastern Ontario. Draft Report. Ontario Ministry of Natural Resources, Eastern Region, Kemptville, Ontario. 80 pages.

Oldham, M. J. 1996. Natural heritage resources of Ontario: Rare vascular plants. Ontario Ministry of Natural Resources, Natural Heritage Information Centre, Peterborough, Ontario. 53 pages.

Literature Cited

Catling, P. M., and **V. R. Brownell.** 1995. A review of the alvars of the Great Lakes region: distribution, floristic composition, biogeography and protection. Canadian Field-Naturalist 109: 143–171.

Catling, P. M., and **V. R. Brownell.** in press. Alvars of the Great Lakes Region. Chapter 24 *in* The Savanna, Barren and Rock Outcrop Communities of North America. *Edited by* R. C. Anderson, J.S. Fralish and J. Baskin. Cambridge University Press, London.

Catling, P. M., and **V. R. Catling [Brownell].** 1993. Floristic composition, phytogeography and relationships of prairies, savannas and sand barrens along the Trent River, eastern Ontario. Canadian Field-Naturalist 107: 24–45.

Catling, P. M., V. R. Catling, and **S. M. McKay-Kuja.** 1992. The extent, floristic composition and maintenance of the Rice Lake Plains, Ontario, based on historical records. Canadian Field-Naturalist 106: 73–86.

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Acceptance of a Gray Wolf, *Canis lupus*, Pup by its Natal Pack After 53 Days in Captivity

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Schultz, Ronald N., Adrian P. Wydeven, and John M. Stewart. 1999. Acceptance of a Gray Wolf, *Canis lupus*, pup by its natal pack after 53 days in captivity. Canadian Field-Naturalist 113(3): 509–511.

We demonstrated that a wolf pup can be taken from the wild, treated in captivity, and be successfully returned to its pack after a 53-day absence.

Key Words: Gray Wolf, *Canis lupus,* sarcoptic mange, treatment, natal pack, parasitism.

On 3 September 1995, we captured (Mech 1974) a female Gray Wolf (*Canis lupus*) in Bayfield County, Wisconsin, apparently suffering from sarcoptic mange. The pup was estimated to be 130–140 days old (Fuller 1989; Van Ballengerghe and Mech 1975) and weighed 4.8 kg, about 32% of the standard for that age (Van Ballenberghe and Mech 1975). She had alopecia over much of her body and displayed symptoms typical of Sarcoptic mange (Todd et al. 1981). Because a wolf at such a low weight had poor potential for survival (Van Ballenberghe and Mech 1975), we removed her from the wild and medically treated her in an isolation pen for possible release back into the wild. We are unaware of other attempts to treat wolves medically in captivity for an extended period and then release them back into the wild. Herein, we describe the treatment and successful release of this wolf pup into the wild after 53 days.

This wolf (255F) was one of four members of the Rainbow Lake Pack. Another member, adult male

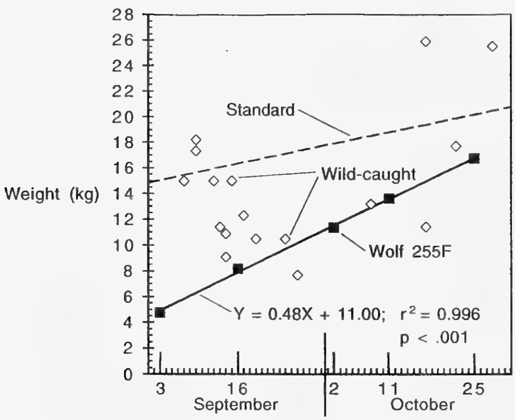

FIGURE 1. Weight gain of Gray Wolf 255F over the course of treatment in captivity. Weight on 25 Oct 95 was estimated by linear regression of prior weights on days in captivity. These data are compared to the standard weights for captive female wolf pups computed by Van Ballenberghe and Meech (1975) from data by Kuyt (1972). Weights for 17 female pups wild-caught during these months (Van Ballenberghe and Mech 1975) are also presented.

223M, was radio collared in 1992, enabling close monitoring of the pack's movements. Pack activity was centered near the Rainbow Lake Wilderness Area in the Chequamegon National Forest (46°24′N, 90°20′W).

The captive facility for wolf 255F was 115 km SE of the pack's territory and consisted of a 3^{-m^2} enclosure with an artificial den (46 × 81 × 61 cm), 200 m from the nearest human dwelling. The territory of the nearest wild wolf pack was 4.6 km away. A captive adult female wolf and an adult female wolf-dog hybrid were also being held at the dwelling.

These animals vocalized periodically, and wolf 255F joined these vocalizations. Treatment of wolf 255F began on the day of capture, with both a sponge-on insecticide, Paramite (VET-KEM, Division of Zoecon Corporation, Dallas, Texas 75234, USA), and 2mg/kg subcutaneous injection of Ivermectin (MSD-AGVET, Division of Merck & Co., Rahway, New Jersey 107065, USA). Treatments were repeated as described for domestic dogs. Wolf 255F was also given LA-200 (Pfizer Animal Health, Division. of Pfizer, Inc., New York, New York 10017, USA), to prevent any infection. Wolf 255F was vaccinated against Canine Distemper-Adenovirus, Type 2-Parainfluenza, Parvovirus, and Leptospira Canicola-Icterohaemorrhagiae Bacterin (Smith Kline Beecham Animal Health, West Chester, Pennsylvania 19280). Fecal samples collected on days 3 and 10 showed no sign of internal parasites or ingested mites (*Sarcoptes scabiei* var *canis*). Wolf 255F was checked once each day at dusk for health status and to provide fresh food and water. Visitations were generally limited to less than 5 minutes, and mild negative conditioning was used to avoid human habitation.

During the first week of captivity, wolf 255F developed severe loose stools possibly from being fed a venison-only diet (*Odocoileus virginianus*) ad lib. Beginning on day 6, wolf 255F's diet was changed to a mixture of 60% venison and 40% dry dog food (Tuffy's, Division of H. J. Heinz, Perham, Minnesota 56573, USA). This 60/40 mixture hardened the stools. Wolf 255F remained on this diet for the rest of her captivity (days 6 to 52).

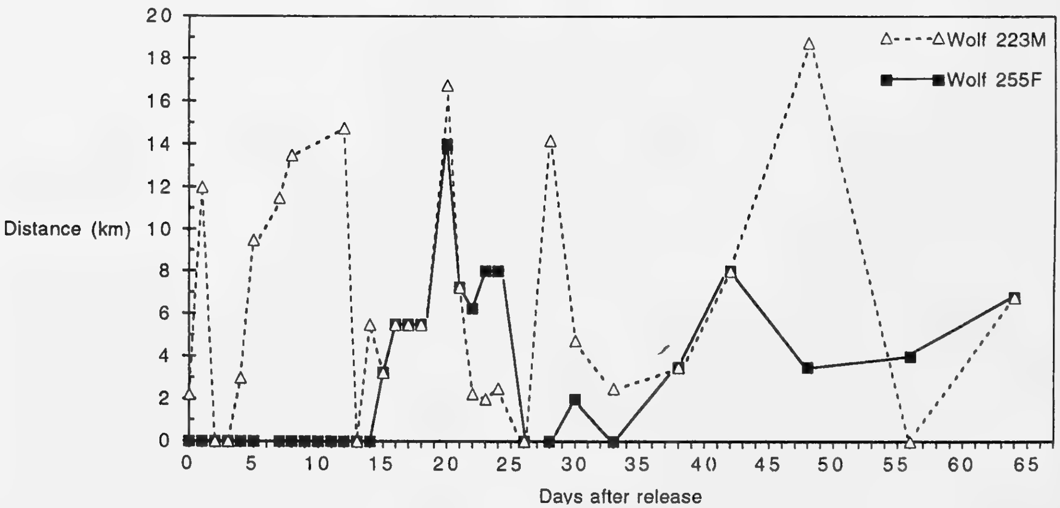

FIGURE 2. Distance of Gray Wolf 255F from the release site on successive days after release. The distance of wolf 233M from the release site is also shown for each successive day.

Wolf 255F's physical response to treatment was dramatic. She showed rapid weight gain ($r^2 = <0.996$, $P < 0.001$; Figure 1). By the time she was ready for release after 53 days in captivity, she weighed an estimated 16 kg (81% of the standard weight). Her alopecia was gone; her underfur and all of the guard hair had grown to nearly normal length. She had not become tame or docile over the course of her time in captivity.

On 12 October, 14 days before release, we immobilized wolf 255F, ear tagged her, and fitted her with a radio collar. We released her where captured, a rendezvous site visited periodically by her pack. Over an 18-day period prior to release, we left deer and beaver carcasses there to attract wolves. Twelve days before release we found fresh wolf tracks there. We released wolf 255F at 08:00 h on 25 October 1995, when wolf 223M was only 400m northwest.

We monitored the locations of wolf 255F and wolf 223M by radio-telemetry from both the ground (triangulation) and air (GPS plotting). Wolf 255F was monitored continuously for the first 72 hours after release. When wolf 223M was within 2 km, his location was also monitored continuously. Then both animals were located daily for the next four weeks, and weekly thereafter.

Wolf 223M did not join wolf 255F on the release day. Wolf 223M moved 13 km NW. Wolf 223M did join 255F on 27 October for 17 hours, but left without her. The next day wolf 223M was located 3km SE of 255F's location. Wolf 255F remained within a few hundred meters of the release site for 2 weeks (25 October–8 November).

The second known contact took place on the 13th day after release. Wolf 255F and wolf 223M were together at the release site for at least 3 hours. On the 15th day wolf 255F left the release site and joined 223M at a regularly used rendezvous site of the Rainbow Lake pack 3.3km SE of the release site (Figure 2).

Wolf 255F had spent 25% of her life away from her packmates. Possibly, the 14 days at the release site were necessary to re-acquaint herself with her pack.

Wolf 255F was found with her natal pack periodically throughout winter, until 27 March 1996, 154 days after her release. At about 1 year of age, in April 1996, wolf 255F dispersed and established a territory 38.4 km to the SW in February 1997. There, she met a dispersing adult male wolf 194M, from Douglas County. On 28 April 1997 wolf 255F died while giving birth to the second of two pups.

During 53 days of captivity and treatment, wolf 255F more than tripled her weight. Ivermectin was effective in treating the apparent mange condition in this wolf similar to findings for dogs (Yazwinski et al. 1981). Although sarcoptes mange mites were not verified on wolf 255F, the alopecia was consistent with mange symptoms (Samuel 1981; Todd et al. 1981). After treatment, the pup was successfully returned to the Rainbow Lake Pack, but probably would not have survived without being treated (Van Ballenberghe and Mech 1975).

Acknowledgments

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Literature Cited

Fuller, T. K. 1989. Denning behavior of wolves in north-central Minnesota. American Midland Naturalist 121: 184–188.

Kuyt, E. 1972. Food habits and ecology of wolves on barren-ground caribou range in the Northwest Territories. Canadian Wildlife Services, Report Series 21. 36 pages.

Mech L. D. 1974. Current techniques in the study of elusive wilderness carnivores. Proceedings of the 11th International Congress of Game Biology 11: 315–322.

Samuel, W. M. 1981. Attempted experimental transfer of sarcoptic mange (*Sarcoptes scabiei* acarina: sarcopticae) among red fox, coyote, wolf and dog. Journal of Wildlife Diseases 17: 343–347.

Todd, A. W., J. R. Gunson, and **W. M. Samuel.** 1981. Sarcoptic mange: An important disease of coyotes and wolves of Alberta, Canada. Pages 706–729 *in* Worldwide Furbearer Conference. Proceedings. *Edited by* J. A. Chapman and D. Pursley. Frostburg, Maryland.

Van Ballenberghe, V., and **L. D. Mech.** 1975. Weights, growth and survival of timber wolf pups in Minnesota. Journal of Mammalogy 56: 44–63.

Yazwinski, T. A., L. Pote, W. Tilley, C. Rodriquez, and **T. Greenway.** 1981. Efficacy of ivermectin against *Sarcoptes scabiei* and *Otodectes cynotis* infestation in dogs. Veterinary Medicine/ Small Animal Clinician 76: 1749–1751.

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An observation of Interspecific Amplexus between Boreal, *Bufo boreas*, and Canadian, *B. hemiophrys*, Toads, with a Range Extension for the Boreal Toad in central Alberta.

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Eaton, Brian R., Chad Grekul, and Cynthia Paszkowski. 1999. An observation of interspecific amplexus between the Boreal, *Bufo boreas*, and Canadian, *B. hemiophrys*, toads, with a range extension for the Boreal Toad in central Alberta. Canadian Field-Naturalist 113(3): 512–513.

We recorded the presence of Boreal Toads approximately 32 km to the northeast of Lac La Biche, Alberta, and an observation of interspecific amplexus between a Boreal Toad male and a Canadian Toad female in the same area. This extends the northeastern limit of the species' range and the area where interspecific amplexus has been observed.

Key Words: Boreal Toad, *Bufo boreas boreas*, Canadian Toad, *Bufo hemiophrys*, interspecific mating, Alberta.

Two species of toad are found in the southern boreal region of Alberta: the Boreal Toad (*Bufo b. boreas*), and the Canadian Toad (*B. hemiophrys*). The Boreal Toad, which is found from southern Alaska to northern California, and from the Pacific coast to the Rocky Mountains, reaches the northeastern limit of its range in Alberta (Stebbins 1985). Canadian Toads are distributed from Fort Smith, Northwest Territories, to northeastern South Dakota, and from eastern Manitoba to central Alberta, where they reach the western edge of their range (Cook 1983). The distributions of the two species overlap in central Alberta (Cook 1983; Russell and Bauer 1993), with this overlap most extensive north of Edmonton (Figure 1).

Boreal Toads were captured at two small lakes in an area approximately 32 km northeast of the town of Lac La Biche, Alberta, during a study of the effects of logging on riparian ecosystems. Amphibian populations at four lakes in this area have been monitored using drift fence and pitfall trap arrays since 1995 (C. Paszkowski, unpublished data). Boreal Toads were trapped at Lake 1 (location = 55°08′ 00″ N, 111°39′40″ W; area of lake = 13.8 ha) in 1995 (4 individuals) and 1996 (1 individual), and at Lake 2 (location = 55°10′00″ N, 111°54′ 30″W; area of lake = 33.1 ha) in 1995 (2 individuals). No Boreal Toads were trapped at either lake in 1997, but Canadian Toads have been trapped at the same lakes at a rate of 6 to 41 individuals per year between 1995 and 1997. Two other Boreal Toads were captured in 1996 during visual searches of small ponds near Lake 1.

Captures of Boreal Toads in this part of Alberta represent an extension of the species' range approximately 20 km to the northeast of what is currently documented in the literature (Cook 1983; Russell and Bauer 1993). Cook (1983; his Figure 34) indicated that Boreal Toads occurred to the east of Lac La Biche, but the two specimens on which this was based (Zoological Museum, University of Alberta) were collected at Square Lake, Alberta. There are three "Square Lake" localities listed for Alberta (Anonymous 1988), one of which is immediately to the east of Lac La Biche, but the actual location at which these individuals were collected was not

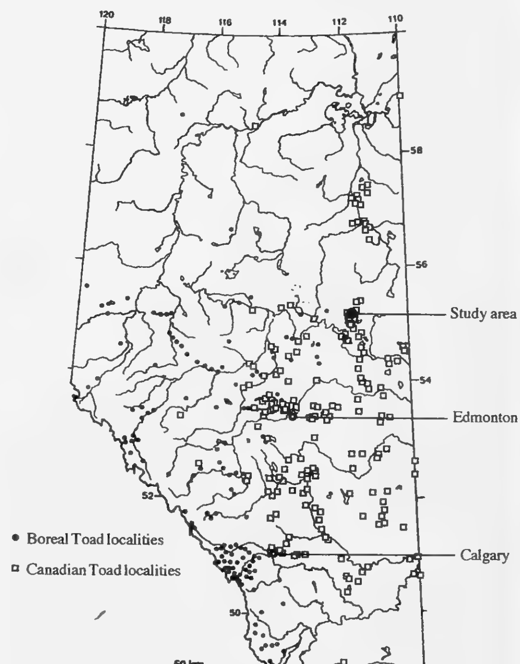

FIGURE 1. Distribution of Boreal Toads and Canadian Toads in Alberta, region of overlap between the two species, and study area. We have not included records which are extreme outliers within the range of the species. Modified from Cook (1983), Russell and Bauer (1993), and Hamilton et al. (1998).

noted. For this reason Russell and Bauer (1993) did not show this location on their distribution map for the Boreal Toad (A. P. Russell, personal communication). However, as the other Square Lakes are located substantial distances outside the present known distribution of the species (one being in Wood Buffalo National Park and the other near the Alberta-Saskatchewan border), we assume here that the assignment of the record to near Lac La Biche is most likely valid.

This extension of the range of the Boreal Toad increases the known area of overlap between Boreal and Canadian toads. Within the previously documented zone of overlap, Cook (1983) found four breeding choruses that contained both Boreal and Canadian toads, with mismatched pairs found at all four sites. One individual that was morphologically clearly a hybrid was captured at a chorus but it is not known if this hybrid was fertile (Cook 1983).

On 5 June 1996 we captured a pair of amplexed toads along the shoreline of Lake 1. The female was a Canadian Toad, weighed 39.5 g, had a snout-to-vent length (SVL) of 6.1 cm, and appeared to be gravid. The male was a Boreal Toad, weighed 22.5 g, and had an SVL of 6.0 cm. The toads were captured at 1445 h when the air temperature was 22°C.

Our observation of a mismatched pair is the only published account other than Cook (1983) of which we are aware that documents mating, or attempted mating, between Boreal and Canadian toads. This record also extends the geographic area over which interspecific interactions may occur, as the nearest mixed chorus observed by Cook (1983) was approximately 110 km to the west of our study area.

Mismatched pairing, and the production of hybrids, between Canadian and Boreal toads appears to be relatively rare, or to have gone unnoticed because of limited study of amphibians in the area of overlap between the two species. Canadian Toads are known to hybridize freely with American Toads (*Bufo americanus*) over a narrow zone in Manitoba (Cook 1983; Green 1983; Green and Pustowka 1997), but seem to hybridize rarely with Boreal Toads (Cook 1983). Whether reproductive isolation of the Boreal Toad and Canadian Toad is a result of reduced viability or fertility of hybrid offspring, or low abundance of one of the two species within the zone of overlap is unknown.

Acknowledgments

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Literature Cited

Anonymous. 1988. Gazetteer of Canada: Alberta. Energy, Mines, and Resources Canada, Ottawa. 64 pages.

Cook, F. R. 1983. An analysis of toads of the *Bufo americanus* group in a contact zone in central northern North America. National Museums of Canada Publications in Natural Sciences Number 3. 89 pages.

Cook, F. R. 1984. Introduction to Canadian amphibians and reptiles. National Museums of Canada, Ottawa. 200 pages.

Green, D. M. 1983. Allozyme variation through a clinial hybrid zone between the toads *Bufo americanus* and *B. hemiophrys* in southeastern Manitoba. Herpetologica 39: 28–40.

Green, D. M., and **C. Pustowka.** 1997. Correlated morphological and allozyme variation in the hybridizing toads *Bufo americanus* and *Bufo hemiophrys*. Herpetologica 52: 218–228.

Hamilton, I. M., J. L. Selnick, H. D. Troughton, A. P. Russell, and **G. L. Powell.** 1998. Status of the Canadian Toad (*Bufo hemiophrys*) in Alberta. Alberta Environmental Protection, Wildlife Management Division, and the Alberta Conservation Association, Wildlife Status Report Number 12. Edmonton, Alberta. 30 pages.

Russell, A. P., and **A. M. Bauer.** 1993. The amphibians and reptiles of Alberta. University of Calgary Press, Calgary, and University of Alberta Press, Edmonton. 264 pages.

Stebbins, R. C. 1985. A field guide to western reptiles and amphibians. Houghton Mifflin Company Boston. 336 pages.

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The False Catshark, *Pseudotriakis microdon* Brito Capello, 1867, New to the Fish Fauna of Atlantic Canada

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Gilhen, John, and Brian W. Coad. 1999. The False Catshark, *Pseudotriakis microdon* Brito Capello, 1867, new to the fish fauna of Atlantic Canada. Canadian Field-Naturalist 113(3): 514–516.

We report the capture, and provide a description and measurements, of the first False Catshark, *Pseudotriakis microdon*, in Canadian waters. This is only the third record of this sole member of the family Pseudotriakidae from the western North Atlantic.

Key Words: False Catshark, *Pseudotriakis microdon*, new record, fish fauna, Canada.

An adult male specimen of the False Catshark, *Pseudotriakis microdon* (Family Pseudotriakidae), measuring 223 cm total length was caught by a halibut trawl, baited with mackerel, at 2100 hours on 20 February 1994. It was taken at a depth of about 558 m in an underwater canyon known to fishermen as “Southwest Cove” about 88 km east of Sable Island and 358.4 km east of Sambro, Halifax County, Nova Scotia at 44°12′N, 58°25′W. This is the first record for this rare species from Canada (Scott and Scott 1988; Coad 1995). The specimen is catalogued in the Nova Scotia Museum of Natural History, Halifax under NSM12550.

Description

This species of large, soft-bodied catshark is the only member of its family and is uniquely distinguished from all other sharks by the extremely long, low and rounded first dorsal fin, which is longer basally than the caudal fin (Figure 1). The body is elongate and the head relatively small. An anal fin is present. There are no spines in the fins. The snout is moderately elongate. The spiracles are large, about equal to eye length, and the nostrils are not connected by a groove to the mouth. Teeth are very small and number over 200 in each jaw. The mouth is large and angular. Each tooth has a narrow cusp and well-developed lateral cusplets. Posterior teeth are comb-like. The elongate eyes have a poorly developed nictitating eyelid (Figure 2). There are five small gill slits, the last two lying over the pectoral fin base. The caudal fin lacks precaudal pits and keels and is not lunate.

Measurements in percent of total length are: snout tip to eye 5.6, snout tip to mouth 5.2, snout tip to pectoral fin origin 17.7, snout tip to first dorsal fin origin 31.6, snout tip to second dorsal fin origin 65.2, snout tip to upper caudal fin origin 82.1, distance between dorsal fins 11.2, distance between second dorsal fin and caudal fin 4.5, mouth width 11.9, horizontal eye diameter 2.5, length first dorsal fin base 22.4, height of first dorsal fin 4.5, length anterior pectoral fin margin 10.3, length dorsal lobe of caudal fin 17.9, distance between spiracles 5.6, distance between outer ends of nostrils 5.6, and distance between pectoral fin tips across belly 28.3.

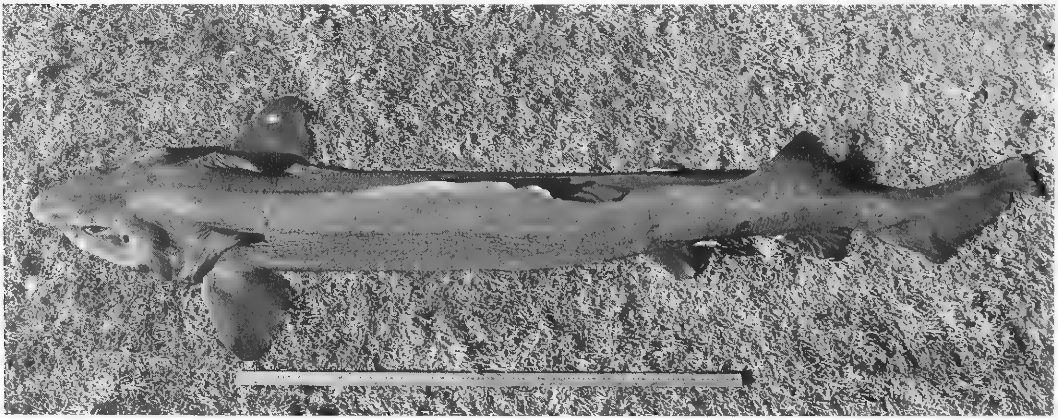

FIGURE 1. False Catshark, *Pseudotriakis microdon*, NSM12550, southeast of Sable Island, Nova Scotia.

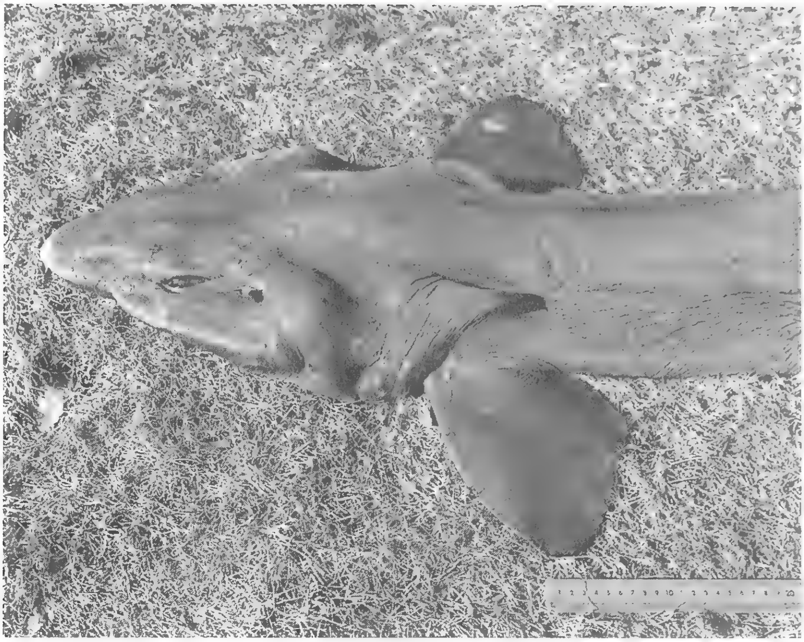

FIGURE 2. Close-up of head of False Catshark, *Pseudotriakis microdon*. NSM12550, southeast of Sable Island, Nova Scotia.

The body is a slate-grey colour with no evident markings. Literature reports state that the body is dark brown in some specimens. Fins are generally darker than the body although in this specimen the first dorsal fin is lighter. Maximum size in the literature is 2.95 m total length for females and 2.7 m for males. The description agrees well with those in Bigelow and Schroeder (1948), Compagno (1984, 1988), and Yano and Musick (1992).

The catshark was caught with 3178 kg of Atlantic Halibut, *Hippoglossus hippoglossus*, and a small number of Spiny Dogfish, *Squalus acanthias*. The False Catshark had been gutted and dressed at capture and then weighed 31.5 kg. The stomach is reported as containing nothing recognisable, just a "jelly-like liquid". Food is reported elsewhere to be predominately benthic bony fishes but also sharks, scavenged moribund or dead fish, squids and octopi, along with garbage from human activities (Yano and Musick 1992). It is an oophagous species, the embryos feeding while in the uterus on yolk material contained in ova produced by the ovaries (Yano 1992). Litter size is two as a result, one young in each uterus.

This species is known world-wide from the deep waters of continental shelves between 200 and 1500 m including the western North Atlantic with one washed ashore at Amagansett, Long Island, New York, on 3 February 1883 (USNM 32516) and probably one from a pound net at Manasquam, New Jersey, in July 1936 (Bigelow and Schroeder 1948). Shallow water records may be abnormal (Compagno 1984). The specimen described here is the first recorded from Canadian waters and only the third from the western North Atlantic.

Acknowledgments

We are indebted to Robert Ackman, Canadian Institute of Fisheries Technology for notifying us of this specimen and for depositing it at the Nova Scotia Museum of Natural History. Details on the capture site were provided by Frank Reyno, captain of the longliner *Short 'n Sassy*. Ron Merrick, Media Services, Nova Scotia Department of Education, did the photography.

Literature Cited

Bigelow, H. B., and **W. C. Schroeder.** 1948. Sharks. *In* Fishes of the Western North Atlantic. Memoir Sears Foundation for Marine Research, Yale University 1: 59–576.

Coad, B. W., with **H. Waszczuk,** and **I. Labignan.** 1995. Encyclopedia of Canadian Fishes. Canadian Museum of Nature, Ottawa and Canadian Sportfishing Productions, Waterdown, Ontario. viii + 928 pages, 128 colour plates.

Compagno, L. J. V. 1984. FAO species catalogue. Sharks of the World. FAO Fisheries Synopsis Number 125, Volume 4, Part 2, x + 251–655 pages.

Compagno, L. J. V. 1988. Sharks of the Order Carcharhiniformes. Princeton University Press, New Jersey. xxii + 486 pages, 21 figures, 35 plates.

Scott, W. B., and **M. G. Scott.** 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. xxx + 731 pages.

Yano, K. 1992. Comments on the reproductive mode of the false cat shark, *Pseudotriakis microdon.* Copeia 1992: 460–468.

Yano, K., and **J. A. Musick.** 1992. Comparison of morphometrics of Atlantic and Pacific specimens of the false catshark, *Pseudotriakis microdon*, with notes on stomach contents. Copeia 1992: 877–886.

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Six-egg clutches of the Mountain Plover, *Charadrius montanus*

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Three six-egg clutches of the Mountain Plover (*Charadrius montanus*) represent the largest clutch size ever reported for this declining Great Plains shorebird. Clutch size in this species is normally three eggs, and six-egg clutches probably represent the laying of a second clutch in the nest by the same female.

Key Words: Mountain Plover, *Charadrius montanus*, clutch size, Montana.

Mountain Plovers (*Charadrius montanus*) are a declining shorebird of the western Great Plains breeding from southeastern Alberta south to Texas (Knopf 1996a). Nearly all clutches of this species contain three eggs (Graul 1975; Knopf 1996b). Four-egg clutches have been reported on six occasions (Graul 1975; Hamas 1985; Knopf 1996b). Herein, we report three incidences of six-egg clutches in the Mountain Plover.

On 2 June 1997, we found a Mountain Plover nest containing six eggs in southern Phillips County, Montana (47°38′N, 108°01′W; cover). The nest was on a small (4 ha) Black-tailed Prairie Dog (*Cynomys luduvicianus*) colony on Bureau of Land Management lands, just north of the Charles M. Russell National Wildlife Refuge boundary. All of the eggs were very similar in size, shape, colouration and marking patterns, suggesting that they were laid by a single female. Mountain Plovers lay eggs that vary widely in these traits among females, with eggs from different females almost always being distinctive (personal observation).

Floatation of the six eggs revealed that all eggs were at least three weeks old. The adult was trapped and colour-banded. On 5 June, the colour-banded adult was incubating all six eggs. The eggs were floated again and determined to be within a few days of hatching. On 12 June, the nest was empty. Lack of disturbance to the nest and presence of minute egg-shell fragments in the nest cup (Mabee 1997) indicated it hatched successfully, probably around 10 June. Although we cannot be sure, it is likely that all six eggs hatched because unhatched eggs in other Mountain Plover nests often remain untouched for weeks (personal observation).

On 24 June 1998, we found another six-egg clutch at Fort Belknap Indian Reservation in Blaine County, Montana (48°20′N, 108°28′W). All of the eggs were very similar in size, shape, colouration and marking patterns, suggesting that they were laid by a single female. Floatation of the six eggs revealed that they were nearly four weeks old and within 1-2 of days of hatching. The adult was trapped and colour-banded. We did not return to the nest-site until 14 July, at which time the nest was empty. Using eggshell evidence (Mabee 1997), we inferred that the nest hatched successfully, although we never saw the adult and young again.

We recently learned of a third six-egg clutch of the Mountain Plover. Kari Bartosiak photographed that clutch on 21 May 1992 on the Thunder Basin National Grassland, approximately 30 km north of Bill, Converse County, Wyoming (43° 12′ N 105° 18′ W). The photograph of that clutch also showed six eggs of similar size, shape, colouration, and markings. The ultimate fate of that nest was not certain, but five eggs were still present and being incubated on 10 June 1992.

Clutch size in Mountain Plovers is highly consistent. Ninety-one percent of 108 nests on the Pawnee National Grassland in northeastern Colorado (Knopf 1996b) and 89% of 371 nests in Phillips County, Montana (SJD) contained three eggs. Incomplete clutches and partial predation of the nests may have biased these figures downward. Four-egg clutches are rare in Mountain Plovers. We have observed two four-egg clutches, one each on the Pawnee National Grassland and in Phillips County. The latter nest contained a runt egg that failed to hatch (SJD). Of two additional four-egg clutches on the Pawnee, only one contained a runt egg that failed to hatch (T. Sordahl, personal communication). We speculate that the six-egg clutches represent two separate clutches of three eggs each that were deposited in the same nest. Some female Mountain Plovers are known to lay two clutches (Graul 1973), one incubated by each member of the pair. We speculate that at each six-egg clutch site, a single female was responsible for laying two clutches in the same nest.

We thank Tim W. Byer, District Wildlife Biologist for the Thunder Basin National Grassland, U.S. Forest Service, for providing a photograph and field notes regarding the Wyoming clutch.

Literature Cited

Graul, W. D. 1973. Adaptive aspects of the Mountain Plover social system. Living Bird 12: 69–94.

Graul, W. D. 1975. Breeding biology of the mountain plover. Wilson Bulletin 87: 6–31.

Hamas, M. J. 1985. A four-egg clutch of the mountain plover. Wilson Bulletin 97: 388–389.

Knopf, F. L. 1996a. Prairie legacies – birds. *In* Prairie Conservation: preserving North America's most endangered ecosystem. *Edited by* F. B. Samson and F. L. Knopf. Island Press, Covelo, California.

Knopf, F. L. 1996b. Mountain Plover (*Charadrius montanus*). *In* The Birds of North America, Number 211. *Edited by* A. Poole and F. Gill. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D. C.

Mabee, T. J. 1997. Using eggshell evidence to determine nest fate of shorebirds. Wilson Bulletin 109: 307–313.

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Unusually High Yellow-billed Cuckoo, *Coccyzus americanus*, Nests

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Wilson, Jennifer K. 1999. Unusually high Yellow-billed Cuckoo, *Coccyzus americanus*, nests. Canadian Field-Naturalist 113(3): 517–518.

Yellow-billed Cuckoos nest much higher than documented, even in forest tree canopies. Previous descriptions of nest sites do not attribute nest heights greater than 14 m to this species. I report Yellow-billed Cuckoo nests in Arkansas at heights as great as 27 m. Location of high nests may be assisted by observation of behavioral cues when nest searching.

Key Words: Yellow-billed Cuckoo, *Coccyzus americanus*, nests, height, Arkansas.

The Yellow-billed Cuckoo (*Coccyzus americanus*) is described as nesting in small to medium-sized trees and vine tangles (Bent 1940; Hamel 1992; Terres 1982). This species is commonly perceived as a midstory-nester. I report the greatest observed range in nesting height for this species at a single locale, and show it capable of nesting much higher than previously documented.

Data were collected at White River National Wildlife Refuge (WRNWR) April–August, 1994–1997. Located in eastern Arkansas and containing 66 000 ha of bottomland hardwood forest, WRNWR is the largest forested wetland tract north of Louisiana. Nuttall Oak (*Quercus nuttallii*), Overcup Oak (*Quercus lyrata*), and Sugarberry (*Celtis laevigata*) are the predominant tree species.

Yellow-billed Cuckoo nests were located on six 50-ha study plots. The approximate latitude and longitude bounds for the six plots were: North, 34°15′; South, 34°13′16″; East, 91°3′26″; West, 91°7′30″. The plots at WRNWR were searched for Yellow-billed Cuckoo nests from the time of their arrival (April–May) until late July. Locations were recorded for nests located while still active, and for terminated nesting attempts that still had Yellow-billed Cuckoo egg shell fragments in or beneath the nest. Nests found while still active are distinguished below. From late July–August of each year, nest heights were collected for all nests located during the breeding season. Nest heights were measured with a Suunto clinometer.

In 1994, mean nest height was 4.9 m (n = 34, 2SE = 1.40, range = 2.8–9.4); in 1995, it was 5.5 m (n = 45, 2SE = 1.20, range = 2.7–13.2); in 1996, it was 5.6 m (n = 75, 2SE = 0.80, range = 1.5—23.4); and in 1997, mean nest height was 8.2 m (n = 117, 2SE=0.80, range=1.4-27.0). Of these, no nests >14 m high were located in 1994 or 1995, 3 were located in 1996 (heights 19.2, 19.6, and 23.4 m), and 11 in 1997 (heights 14.3, 16, 16.2, 16.4, 17.4 (2), 18.8, 19, 22, 25, and 27 m). Of the three high nests located in 1996, two were located while active. Of the 10 high

*See Documents Cited section.

nests found in 1997, six were located while active. As both nest heights and sample sizes increased annually, this likely reflects an increase in nest-searching effectiveness for high nests rather than an increase in nest height.

Nest heights documented in other regions are not as extreme as in Arkansas. Observed mean nest height in Ontario is 1–2 m, with range = 0.6–6.0, n = 55 (Peck and James 1983). In California, the mean = 4.8 m, with range = 1.3–13.0, s.d. = 3.01, and n = 99 (S. Laymon, personal communication, 1998). In Kentucky, the mean = 2.5 m, range = 0.8–6.1, n = 14 (Mengel 1965). Rosenberg et al. (1991) list a range of 4.5–14 m for the Lower Colorado River Valley.

Most Yellow-billed Cuckoos are secretive during human presence during the breeding season and alter their behavior (Hamilton and Hamilton 1965). This increases the likelihood of overlooking nests constructed in locations where they are difficult to see, such as forest canopies. However, certain vocalizations are associated with nest visitation and may assist in nest location. In California, both parents commonly utter the "kawlp" call before nest visits (Laymon and Halterman 1985*). In Arkansas, I also have noticed both parent birds uttering a short, deep-noted "kaow" call upon nest approaches. However, the only time I observed this, without the aid of a concealing blind, was in the case of nests constructed in the canopy.

At WRNWR, Yellow-billed Cuckoos nesting in the midstory layer typically do not emit these vocalizations, or approach nests, in the presence of an unconcealed observer (I have attributed this to the secretive nature of the bird). Although these behavioral cues were not helpful in locating nests low in height at WRNWR, behavioral cues sometimes resulted in location of high nests. The ability to directly observe nest visits or to use vocalizing locations to narrow the search area directly resulted in, or assisted in, the location of one of the two active high nests located in 1996 (height 23.4 m), and four of the six active high nests located in 1997 (heights 16.2, 16.4, 19, and 25 m). Utilizing this information in areas populated with Yellow-billed Cuckoos but lacking in midstory nests may increase nest finds for this species.

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Documents Cited (marked * in text)

Laymon, S. A., and **M. D. Halterman.** 1985. Yellow-billed Cuckoos in the Kern River Valley: 1985 population, habitat use, and management recommendations. Unpublished report. The Nature Conservancy, Weldon, California.

Literature Cited

Bent, A. C. 1940. Yellow-billed Cuckoo. Pages 54–66 *in* Life histories of North American cuckoos, goatsuckers, hummingbirds, and their allies. United States National Museum Bulletin 176.

Hamel, P. B. 1992. The land manager's guide to the birds of the South. The Nature Conservancy, Southeastern Region, Chapel Hill, North Carolina.

Hamilton, W. J., III, and **M. E. Hamilton.** 1965. Breeding characteristics of Yellow-billed Cuckoos in Arizona. Proceedings of the California Academy of Sciences, 4th series, 32: 405–432.

Mengel, R. M. 1965. The birds of Kentucky. Ornithological Monograph number 3. Allen Press, Lawrence, Kansas.

Peck, G. K., and **R. D. James.** 1983. Breeding birds of Ontario: nidiology and distribution. Volume 1: Nonpasserines. Royal Ontario Museum Life Science Miscellaneous Publication, Toronto, Ontario.

Rosenberg, K. V., R. D. Ohmart, W. C. Hunter, and **B. W. Anderson.** 1991. Birds of the Lower Colorado River Valley. University of Arizona Press, Tucson.

Terres, J. K. 1982. The Audubon Society encyclopedia of North American birds. Alfred Knopf, New York.

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Temporal Distribution of Rubbing and Scraping by a High-density White-tailed Deer, *Odocoileus virginianus*, Population in Georgia

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Miller, Karl V., and R. Larry Marchinton. 1999. Temporal distribution of rubbing and scraping by a high-density White-tailed Deer, *Odocoileus virginianus*, population in Georgia. Canadian Field-Naturalist 113(3): 519–521.

We characterized spatial and temporal distribution of rubs and scrapes made by male White-tailed Deer in a high-density deer herd in northern Georgia. Species selected for rubbing included Hazel Alder (*Alnus serrulata*), Eastern Red Cedar (*Juniperus virginiana*), Loblolly Pine (*Pinus taeda*), and sumac (*Rhus* spp.). Unlike previous reports, rubs were made at a relatively constant rate throughout the breeding season. Peak scraping activity occurred 2-3 weeks before peak breeding. Density of rubs (1423/km^2) and scrapes (211/km^2) were higher than reported from previous studies, likely due to the high estimated deer density (37/km^2) and older male age structure.

Key Words: White-tailed Deer, *Odocoileus virginianus*, behavior, signpost, rutting behavior, Georgia.

Antler rubs are signposts used to establish White-tailed Deer (*Odocoileus viriginianus*) dominance hierarchies in preparation for the breeding season (Moore and Marchinton 1974; Hirth 1977). Socially-significant odors deposited on the rubbed tree likely originate from sudoriferous glands in the forehead region that become increasingly active during the breeding season (Atkeson and Marchinton 1982). Rubs have a clumped spatial distribution (Moore and Marchinton 1974; Kile and Marchinton 1977; Miller et al. 1987) that may be due to the male's delineation of dominance areas or to the location of preferred rub trees. In studies conducted in Georgia and South Dakota, males apparently selected aromatic tree species for rubbing (Kile and Marchinton 1977; Oehler et al. 1995); however, no selection for aromatic species was indicated in a study from Maine (Benner and Bowyer 1988).

A scrape is initiated by a male scent-marking a low hanging branch. The animal then paws a shallow depression under the branch into which he urinates. Scrapes generally are made by dominant males (Hirth 1977) and serve as olfactory signals to establish dominance areas and to communicate with does. In a Michigan study, bucks > 2.5 years old began making scrapes 2 months before the onset of breeding, whereas yearlings did not scrape until about 1 week before the first doe came into estrus (Ozoga and Verme 1985). Also, yearlings only made 15% as many scrapes as prime-age individuals.

Previous studies of the temporal distribution of rubbing and scraping are limited. Rubbing peaks early in the breeding season near the time of velvet removal, whereas peak scraping occurs just before the peak of conception dates (Moore and Marchinton 1974; Kile and Marchinton 1977; Ozoga 1989). Other studies have suggested that variations in population density, age structure, and sex ratio may affect the timing and length of the breeding season (Gruver et al. 1984). Herd demography also affects behaviors associated with breeding, such as rubbing and scraping, both temporally and quantitatively (Ozoga and Verme 1985; Miller et al. 1987). Since Miller et al. (1991) hypothesized that signposts produced by male White-tailed Deer are a source of priming pheromones which synchronize estrous cycles, variations in signposting activity may be responsible, at least in part, for variations in breeding chronology. In this study, we report the temporal distribution of rubbing and scraping activity by a high density deer herd in Georgia to further describe demographic influences on signposting. We also further investigated selection of tree species for rubbing.

Study Area and Methods

We conducted the study on the 304-ha Whitehall Forest owned by The University of Georgia, School of Forest Resources and located in Clarke County, Georgia. Habitat types include Oak (*Quercus* spp.)/Hickory (*Carya* spp.), mixed Pine (*Pinus* spp.)/hardwood, planted pine, pastures, old fields, and clearcuts. Hunting is prohibited although 10 deer/year are collected to monitor herd health.

Eleven east-west transects, totalling 14 km, were established at 200-m intervals throughout the area. From 1 September through 31 January 1986, all transects were surveyed weekly and all rubs and scrapes within 9 m of the line were recorded. Species available for rubbing were determined on 247 habitat plots (20 m^2) located randomly along the transects. In each plot, woody stems 0.6 to 6.0 cm in diameter were identified. This diameter range included 95% of the rubs measured. Habitats were classified as hardwood, bottomland hardwood and wet areas, pine, pine/hardwood, clearcuts and edges, and open areas. Rubbing and scraping habitat and species selection for rubbing were tested using chi-square analysis and Bonferroni z statistic analyses (Neu et al. 1974).

Population densities and fawn to adult ratios were estimated using bimonthly spotlight counts from

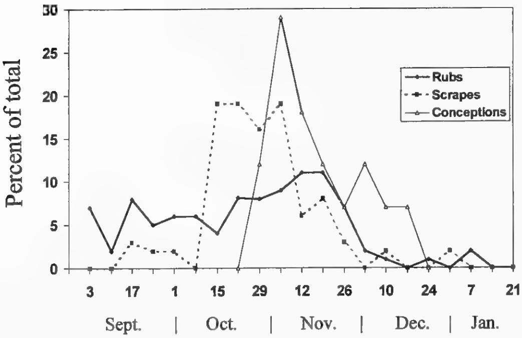

FIGURE 1. Temporal distribution of White-tailed Deer rubs, scrapes, and conception dates on Whitehall Experimental Forest, Clarke Co., Georgia from September 1986 through January 1987.

September 1986 through February 1987. Surveys began 30 minutes after sunset and lasted approximately 1.5 hours. Survey routes averaged 9.3 km. Spotters recorded deer seen within an estimated 100 m of the road and the perpendicular distance to the deer was estimated. Densities were estimated using the Leopold method (Robinette et al. 1974) because it yields fairly good population estimates in areas with variable sighting distances. During April following the surveys, 18 adult does were collected from the area and fetuses were aged (Hamilton et al. 1985) to determine conception dates.

Results and Discussion

Spotlight surveys on the area yielded an estimated mean deer density of 37/km^2 (95% CI 25-49/km^2). The overall fawn to adult female ratio of observed deer was 1:1.7. Seventeen of 18 does collected were pregnant. Range of conception dates was nine weeks and peaked during the first week of November (Figure 1).

Three hundred fifty-one rubs were located during the study resulting in an estimated rub density of 1423/km^2. Average length of the rubbed area was 52 cm (14-97 cm) and mean diameter of the rubbed trees was 24 mm (4-103 mm). Mean diameter of rubbed trees is larger than reported by Kile and Marchinton (1977) and Miller et al. (1987) likely due to the older age structure of males on the unhunted area. The density of > 2.5-year-old males was a minimum of 1.3/km^2, based on sightings of individually identifiable bucks, whereas Miller et al.'s (1987) highest estimated density on areas subjected to hunting was 1 mature buck/km^2. Similarly, the density of 1423 rubs/km^2 is higher than previously reported (Kile and Marchinton 1977; Miller et al. 1987), likely due to a higher density of mature males as suggested on other areas (Ozoga and Verme 1985).

Rubbing activity remained relatively constant throughout the study until mid-December (Figure 1). Unlike previous studies (Kile and Marchinton 1977), rubbing frequency did not peak early in the breeding season following velvet removal. Likely the recorded decline in rubbing activity in their study was due

TABLE 1. Trees selected and avoided for rubbing by White-tailed Deer, Whitehall Experimental Forest, Clarke Co., Georgia, from September 1986 through January 1987.

Species[a]	Number of rubs observed	Percentage of rubs observed	Proportion of trees available
Pinus taeda	58	18.1[b]	10.6
Quercus spp.	32	10.0[c]	16.4
Rhus spp.	24	7.5[b]	3.0
Cornus florida	22	6.9	6.5
Ostrya virginiana	22	6.9	8.6
Prunus spp.	20	6.2	4.2
Carya spp.	19	5.9	6.1
Acer spp.	18	5.6	8.9
Alnus serrulata	16	5.0[b]	1.2
Oxydendrum arboreum	13	4.1	0.8
Ligustrum sinense	12	3.8[c]	7.6
Juniperus virginiana	11	3.4[b]	0.3
Cercis canadensis	9	2.8	1.8
Crataegus spp.	9	2.8	1.2
Liriodendron tulipifera	9	2.8	1.7
Liquidambar styraciflua	8	2.5[c]	13.9
Vaccinium spp.	7	2.2	4.2
Rhododendron spp.	6	1.9	0.6
Nyssa sylvatica	5	1.6	0.4
TOTAL	320	100	98

[a]Only rubbed species with adequate sample sizes ($n \geq 5$) are listed (Neu et al. 1974).
[b]Use greater than expected ($p \leq 0.05$)
[c]Use less than expected ($p \leq 0.05$)

to shifts in habitat use by deer on their study area. Their surveys were conducted in Loblolly Pine stands and Deer activity likely shifted to Oak habitats as mast began to drop in October. Similar spatial shifts in rubbing activity in response to mast availability have been reported (Miller et al. 1987). In our study, habitat types were highly interspersed, and all habitats were surveyed in proportion to their occurrence on the study area. Therefore, the temporal distribution of rubs we recorded likely was not biased by variable mast availability.

Of 38 genera of trees and shrubs available on the area, 32 were rubbed. Proportion of species used differed from expected ($P < 0.001$, $\chi^2 = 313.78$, 27 df). Hazel Alder, Eastern Red Cedar, Loblolly Pine, and Sumac were preferred for rubbing ($P < 0.05$, Bonferroni z statistic) while oak (*Quercus* spp.), Privet (*Ligustrum sinense*), and Sweetgum (*Liquidambar styraciflua*) were avoided (Table 1). Preferred species often possessed aromatic properties as reported in previous studies (Kile and Marchinton 1977; Miller et al. 1987; Oehler et al. 1995). Habitats used for rubbing were not in proportion to availability ($P < 0.005$, $\chi^2 = 55.61$, 5 df). Hardwoods, clearcuts, and edges were preferred ($P = 0.05$), while pine/hardwood habitats were avoided.

A total of 52 scrapes were located yielding a scrape density of 211/km^2. Scraping peaked during the four-week period from mid-October through mid-November, 2-3 weeks prior to the peak of conception dates (Figure 1). Eighty-seven percent of the scrapes had overhanging branches averaging 145 cm (108-165 cm) above ground. Some scrapes in the study were pawed repeatedly for up to three consecutive weeks, and many that were not had fresh tracks in them for up to two weeks. Habitats used for scraping were not used in proportion to availability ($P < 0.001$, $\chi^2 = 19.00$, 5df). Hardwoods were preferred while pine habitats were avoided ($P < 0.05$).

Many of the differences between this study and the study of Kile and Marchinton (1977) probably reflect differences in herd density and age structure. Deer density on Kile and Marchinton's study area was about 10/km^2 (Georgia Department of Natural Resources, personal communication), whereas our pre-collection density estimate was 37 deer/km^2. Differences in deer density and adult buck density could account for the differences in rub and scrape densities. Additionally, since we sampled habitats in proportion to their occurrence on the study area, the temporal distribution of rubs and scrapes likely depict an unbiased description of signpost activity.

Acknowledgments

This study was funded by McIntire-Stennis Project GEO-0093-MS. We thank T. R. Litchfield for his contribution to field work, data analysis, and manuscript preparation. R. J. Warren and M. H. Smith provided critical reviews of earlier drafts of this manuscript.

Literature Cited

Atkeson, T. D., and **R. L. Marchinton.** 1982. Forehead glands in white-tailed deer. Journal of Mammalogy 63: 613–617.

Benner, J. M., and R. T. Bowyer. 1988. Selection of trees for rubs by white-tailed deer in Maine. Journal of Mammalogy 69: 624–627.

Gruver, B. J., D. C. Guynn, Jr., and **H. A. Jacobson.** 1984. Simulated effects of harvest strategy on reproduction in white-tailed deer. Journal of Wildlife Management 48: 535–541.

Hamilton, R. J., M. L. Tobin, and **W. G. Moore.** 1985. Aging fetal white-tailed deer. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 39: 389–395.

Hirth, D. H. 1977. Social behavior of white-tailed deer in relation to habitat. Wildlife Monographs 53: 1–55.

Kile, T. L., and **R. L. Marchinton.** 1977. White-tailed deer rubs and scrapes spatial, temporal, and physical characteristics and social role. American Midland Naturalist 97: 257–266.

Miller, K. V., R. L. Marchinton, and **W. M. Knox.** 1991. White-tailed deer signposts and their role as a source of priming pheromones: a hypothesis. Pages 455–458 *in* Global trends in wildlife management. *Edited by* B. Bobek, K. Perzanowski, and W. Regelin. Transactions of the 18th International Union of Game Biologists Conference, Krakow, Poland.

Miller, K. V., K. E. Kammermeyer, R . L . Marchinton, and **E. B. Moser.** 1987. Population and habitat influences on antler rubbing by white-tailed deer. Journal of Wildlife Management 51: 62–66.

Moore, W. G., and **R. L. Marchinton.** 1974. Marking behavior and its social function in white-tailed deer. Pages 447–456 *in* The behaviour of ungulates and its relation to management. *Edited by* V. Geist and F. Walther. IUCN, New Series, Publication Number 24, Morges, Switzerland.

Neu, C. W., C. R. Byers, and **J. M. Peek.** 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38: 541–545.

Oehler, M. W., Sr., J. A. Jenks, and **R. T. Bowyer.** 1995. Antler rubs by white-tailed deer: the importance of trees in a prairie environment. Canadian Journal of Zoology 73: 1383–1386.

Ozoga, J. J. 1989. Temporal pattern of scraping behavior in white-tailed deer. Journal of Mammalogy 70: 633–636.

Ozoga, J. J., and **L. J. Verme.** 1985. Comparative breeding behavior and performance of yearling vs. prime-age white-tailed bucks. Journal of Wildlife Management 49: 364–372.

Robinette, W. L., C. M. Loveless, and **D. A. Jones.** 1974. Field tests of strip census methods. Journal of Wildlife Management 38: 81–96.

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Common Loon, *Gavia immer*, Feeds on Pacific Giant Octopus, *Octopus dofleini*

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Wright, Kenneth G. 1999. Common Loon, *Gavia immer,* feeds on Pacific Giant Octopus, *Octopus dofleini*. Canadian Field-Naturalist 113(3): 522.

I observed a Common Loon (*Gavia immer*) feeding on a cephalopod, the Pacific Giant Octopus (*Octopus dofleini*) in southern coastal British Columbia. I could not determine whether the observed loon had depredated the octopus or was scavenging. Glaucous-winged Gulls (*Larus glaucescens*) were also observed foraging on the carcass. This is the first reported case of a loon consuming a large cephalopod.

Key Words: Common Loon, *Gavia immer,* Pacific Giant Octopus, *Octopus dofleini*, feeding, British Columbia.

Loons show tremendous adaptability and opportunism in prey selection. McIntyre and Barr (1997) state that the Common Loon (*Gavia immer*) is an opportunistic forager, eating primarily fish and other aquatic vertebrates; and occasionally some invertebrates. The versatility shown by Common Loons includes an observation of feeding on American Lobsters (*Homarus americanus*; Creaser et al. 1993). Scavenging by loons has apparently not been described previously.

Observation

On 22 February 1997 (~13:00 PST) a Common Loon was observed consuming prey on the surface, approximately 75 m off the SE shore of Quadra Island (50°02′ N, 125°10′ W), which lies at the northern extent of the Strait of Georgia, British Columbia.

The loon was repeatedly dipping its head in the water. A closer examination with a 60× spotting scope revealed the distinctive white ventral suckers and red dorsal flesh of a Pacific Giant Octopus (*Octopus dofleini*) arm, approximately 60 cm in length. Its estimated maximum basal girth was 5-10 cm and appeared to be the entire arm section. As the head of the carcass wasn't observed, it is difficult to estimate the total body length, however, assuming the total arm observed was intact the overall body length of the animal must have been at least 80-100 cm. The loon continued to position the arm until it was appropriately aligned, and proceeded to swallow it after several minutes had lapsed while it was handled. A few Glaucous-winged Gulls (*Larus glaucescens*) were also feeding on an octopus on the waterline perpendicular to the loon; presumably this was the same octopus on which the loon fed. Undoubtedly, the octopus had partially decayed, otherwise the loon would have had difficulty severing the arm.

Discussion

Although the Red-throated Loon (*G. stellata*) has been documented consuming squid at Igloolik Island, Northwest Territories (Palmer 1962), this appears to be the first observation of a loon feeding on octopus or any other large cephalopod. Although scavenging by loons hasn't been reported in the literature, given the size of the prey animal, it remains doubtful that the loon depredated the octopus.

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I thank Martin K. McNicholl and Alan E. Hutchinson for bringing some pertinent literature to my attention and the former for his comments on an earlier draft. Robert W. Butler, Anthony J. Erskine and an anonymous reviewer also constructively commented on the manuscript.

Literature Cited

Creaser, E. P., H. C. Perkins, and **F. Pierce.** 1993. Common Loons feeding on lobsters. Maine Naturalist 1: 223–224.

McIntyre, J. W., and **J. F. Barr**. 1997. Common Loon (*Gavia immer*). Pages 1–32 *in* The birds of North America, Number 313. *Edited by* A. Poole and F. Gill. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C.

Palmer, R. S. *Editor.* 1962. Handbook of North American birds. Volume 1. Loons through flamingos. Yale University Press, New Haven and London.

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Long-billed European Starlings, *Sturnus vulgaris*

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Pearson, Roy Douglas. 1999. Long-billed European Starlings, *Sturnus vulgaris*. Canadian Field-Naturalist 113(3): 523–524.

A single presumed female European Starling (*Sturnus vulgaris*) with an unusually long, curved bill was observed and photographed in April-June 1998 at the University of Toronto. Two other long-billed specimens are in collections of the Royal Ontario Museum.

Key Words: European Starling, *Sturnus vulgaris*, bill, heterochrony, atavism, Ontario.

A single European Starling (*Sturnus vulgaris*), presumably a female (pale ring in the iris, and multiple mounting of the bird by conspecifics were witnessed), with an unusually long bill was sighted at the University of Toronto downtown campus (300 Huron Street) from 28 April to 14 June 1998.

FIGURE 1. Long-billed European Starling photographed 3 June 1998, University of Toronto campus, by Vincenzo Pietropaolo.

The bird was photographed and videotaped (8–9 minutes) and appeared unhampered in its feeding and behaviour. Normal and successful feeding (typical of the species) by probing was seen to be at the same rate as other starlings in the immediate vicinity. Also, normal bill-wiping was observed at feeding cessation.

A. R. Goldsmith (University of Bristol, United Kingdom, personal communication) informed me that a starling seen in the wild with an outrageously overgrown bill in the United Kingdom was reported to a colleague. A check of the Royal Ontario Museum ornithological collection found two specimens of *Sturnus vulgaris* with abnormal bills. One was collected in 1949 [female] ROM 76216 by Ross Baker 28 January, in Toronto, Ontario, and the other [male] ROM 91797, by Lee Clark, 9 June 1959, in Agincourt, Ontario. The notations on the tags of these birds indicate that both were collected for reason of "elongated upper mandible" and "long bill". Both had exposed bill lengths of 36–38 mm. Judging from the photo and videotape of the bird here described, its estimated bill-length would be close to 50 mm — twice the length of the average European Starling bill as described by Feare (1984).

Several competing hypotheses that could explain such bill growth include: heterochronic or atavistic growth; physiological/endocrine imbalance; change in diet/feeding; too little bill-wiping and probing. Feare (1984) points out that the Sturnidae presents a feeding dichotomy of arboreal and terrestrial foraging. The more primitive forms were chiefly arboreal feeders. Some modern species take nectar, and nectar feeding has been recently reported by Feare (1993) in *Sturnus vulgaris*. There have been, however, no reports of a specialized bill adaptation for nectar feeding within the family. The mutant witnessed and reported here is reminiscent of the type of bill seen in members of Nectariniidae and Trochilidae, and could conceivably represent an atavism in the family Sturnidae.

Acknowledgments

I thank Jim Rising, University of Toronto, for helping to confirm the bird was not an exotic, and Mark Peck (Royal Ontario Museum) who assisted me in finding the other specimens in the ROM collections. Thanks also to A. J. Erskine for providing helpful comments on an earlier draft of the manuscript.

Literature Cited

Feare, C. J. 1984. The Starling. Oxford University Press. New York.

Feare, C. J. 1993. Nectar feeding in European Starlings. Wilson Bulletin 105: 194.

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News and Comment

Notices

Canadian Species at Risk April 1999

This list, 26 pages, was issued by COSEWIC (Committee on the Status of Endangered Wildlife in Canada), after its April 1999 meeting and includes 1999 new and revised designations as well as all previous ones, additional lists of species examined and designated as not at risk, those examined and placed in the indeterminate category because of insufficient scientific information, as well as a record of status reexaminations. Copies can be obtained from COSEWIC Secretariat s/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3

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1999 Newly listed or (*) reexamined in 1999

EXTINCT

FISH	Stickleback, Benthic Hadley Lake (*Gasterosteus* sp.) BC
	Stickleback, Limnetic Hadley Lake (*Gasterosteus* sp.) BC

EXTIRPATED

MOLLUSCS	Wedgemussell, Dwarf (*Alasmidonta heterodon*) NB
LEPIDOPTERANS	Butterfly, Frosted Elfin (*Caollophrys* [*Incisalia*] *irus* ON
	Butterfly, Island Marble (*Euchloe ausonides*) BC

ENDANGERED

BIRDS	*Owl, Barn (*Tyto alba*) (Eastern population) ON [uplisted]
	*Owl, Northern Spotted (*Strix occidentalis caurina*) BC [no change]
	*Tern, Roseate (*Sterna dougallii*) NS, QC [uplisted]
	*Warbler, Kirtland's (*Dendroica kirtlandii*) ON, QC [no change]
REPTILES	Snake, Sharp-tailed (*Contia tenuis*) BC
MOLLUSCS	Bean, Rayed (*Villosa fabalis*) ON
	Lampmussel, Wavey-rayed (*Lampsilis fasciola*) ON
	Riffleshell, Northern (*Epioblasma torulosa rangiana*) ON
PLANTS	*Agalinis, Gattinger's (*Agalinis gattingeri*) ON [no change]
	*Agalinis, Skinner's (*Agalinis skinneriana*) ON [no change]
	Ammania, Scarlet (*Ammannia robusta*) BC, ON
	*Avens, Eastern Mountain (*Geum peckii*) NS [no change]
	*Clover, Slender Bush (*Lespedeza virginica*) ON [no change]
	*Coreopsis, Pink (*Coreopsis rosea*) NS [no change]
	*Ginsing, American (*Panax quinquefolium*) ON, QC [uplisted]
	Goldenrod, Showy (*Solidago speciosa* var. *rigidluscula*) ON
	*Lady's-slipper, Small White (*Cypripedium candidum*) MB, ON [no change]
	*Mulberry, Red (*Morus rubra*) ON [uplisted]
	*Pogonia, Nodding (*Tripora trianthophora*) ON [uplisted]
	Sedge, Juniper (*Carex juniperorum*)
	*Thistle, Pitcher's (*Cirsium pitcheri*) ON [uplisted]
	Toothcup (*Rotala ramosior*) BC, ON
	*Tree, Cucumber (*Magnolia acuminata*) ON [uplisted]
	*Twayblade, Purple (*Liparis liliifolia*) ON [uplisted]

THREATENED

MAMMALS	Whale, Killer (*Orcinus orca*) (North Pacific "resident" populations)
BIRDS	*Falcon, Anatum Peregrine (*Falco peregrinus anatum*) AB, BC, MB, NB, NF, NS, NT, NU, ON, QC, SK, YT [downlisted]
	Pipit, Sprague's (*Anthus spragueii*) AB, MB, SK
AMPHIBIANS	*Toad, Fowler's (*Bufo fowleri*) [uplisted] ON

REPTILES
Snake, Eastern Fox (*Elaphe vulpina gloydi*) ON
Snake, Queen (*Regina septemvittata*) ON

FISH
Lamprey, Morrison Creek (*Lampetra richardsoni*) BC
*Stickleback, Benthic Paxton Lake (*Gasterosteus* sp.) BC [no change]
Stickleback, Benthic Vananda Creek (*Gasterosteus* sp.) BC
*Stickleback, Limnetic Paxton Lake (*Gasterosteus* sp.) BC [no change]
Stickleback, Limnetic Vananda Creek (*Gasterosteus* sp.) BC

MOLLUSCS
*Abalone, Northern (*Haliotis kamtschatkana*) BC

PLANTS
*Gentian, Plymouth (*Sabatia kennedyana*) NS [no change]
*Golden Crest (*Lophiola aurea*) NS [no change]
*Water-pennywort (*Hydrocotyle umbellata*) NS [downlisted]

VULNERABLE

MAMMALS
*Bear, Polar (*Ursus maritimus*) MB, NF, NT, NU, ON, QC [no change]
*Beaver, Mountain (*Aplodontia rufa*) BC [uplisted]
*Prairie Dog, Black-tailed (*Cynomys ludovicianus*) SK [no change]
Whale, Killer (*Orcinus orca*)(North Pacific "transient" population)

BIRDS
*Bittern, Least (*Ixobrychus exilis*) MB. NB, ON, QC [no change]
*Falcon, Peale's Peregrine (*Falco peregrinus pealei*) NF, NT, NU, QC, YT [no change]
*Owl, Barn (*Tyto alba*) (Western population) BC [no change]
*Owl, Flammulated (*Otus flammeolus*) BC [no change]
Rail, Yellow (*Coturnicops noveboracensis*) AB, MB, NB, NS, NT, NU, ON, QC, SK
Thrush, Bicknell's (*Catharus bicknelli*) NB, NS, QC
Woodpecker, Lewis' (*Melanerpes lewis*) BC

AMPHIBIANS
Frog, Northern Red-legged (*Rana aurora*) BC
Salamander, Spring (*Gyrinophillus porphyriticus*) QC
Toad, Great Plains (*Bufo cognatus*) AB, MB, SK

REPTILES
Snake, Butler's Garter (*Thamnophis butleri*) ON

FISH
Shiner, Bridle (*Notropis bifrenatus*) ON

PLANTS
Aster, Crooked-stemmed (*Aster prenanthoides*) ON
Aster, Willow (*Aster praealtus*) ON
Hairgrass, Mackenzie (*Deschampsia mackenzieana*) SK
*Oak, Shumard (*Quercus shumardii*) ON [no change]
*Plantain, Indian (*Cacalia plantaginea*) ON [no change]
*Thrift, Athabasca (*Armeria maritima* ssp. *interior*) SK [downlisted]

NOT AT RISK

MAMMALS
*Bear, American Black (*Ursus americanus*) all provinces & territories except PE (no change)
Seal, Grey (*Halichoerus grypus*) (Atlantic coastal waters)
Seal, Harbour (*Phoca vitulina richardsi*) (North Pacific coastal waters)
Wolf, Gray (*Canis lupus occidentalis*) AB,BC,MB.NF,NT,NU,ON,QC,SK,YK
Wolf, Gray (*Canis lupus nubilus*) BC

BIRDS
*Tern, Caspian (*Sterna caspia*) AB,BC,MB,NF,NT,NU,ON,QC,SK [downlisted]
*Warbler, Prairie (*Dendroica discolor*) ON [downlisted]

AMPHIBIANS
Ensatina (*Ensatina eschscholtzii*) BC
Frog, Northern Leopard (*Rana pipiens*) (eastern population) NB,NS,ON,QC
Frog, Pickerel (*Rana palustris*) NB, NS, ON, QC
Salamander, Four-toed (*Hemidactylium scutatum*) NB, NS, ON, QC
Salamander, Northern Dusky (*Desmognathus fuscus*) ON, QC [NB]
Salamander, Northwestern (*Ambystoma gracile*) BC
Treefrog, Cope's Gray (*Hyla chrysoscelis*) MB

FISH
Shiner, Weed (*Notropis texanus*) MB

PLANTS
Aster, Short's (*Aster shortii*) ON
*Willow, Tyrrell's (*Salix tyrrellii*) NT, SK [downlisted]

INDETERMINATE (insufficient scientific information)

MAMMALS
Seal, Harbour (*Phoca vitulina concolor*) (Atlantic and Arctic coastal waters)
Whale, Killer (*Orcinus orca*) (Northern Atlantic and Arctic populations)
Wolf, Gray (*Canis lupus arctos*) NT, NU
Wolf, Gray (*Canis lupus lycaon*) ON, QC

FISH
Whitefish, Mira River (*Coregonus clupeaformis*) NS

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Marine Turtle Newletter

Number 84, April 1999, contains an editorial: Update on the Inter-American Convention for the Protection and Conservation of Sea Turtles; articles: Sea Turtles in the South of Bioko Isand (Equatorial Guinea), Historical Overview of Marine Turtle Exploitation, Ascension Island, South Atlantic; and notes Browsing of Mangroves by Green Turtles in Western Australia, University Project on the Study and Conservation of Cuban Sea Turtles; Announcements; Meeting Reports; Letters to Editors; News & Legal Briefs; Recent Publications.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, UK; e-mail MTN@swan.ac.uk; Fax +44 1792 295447.

Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA;
e-mail RhodinCRF@aol.com; Fax + 1 978 840 8184.
MTN website is: <http://www.seaturtle.org/mtn/>

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF)

Number 32, April 1999, contains: Effects of Volcanic Activity on the Endangered Mountain Chicken Frog (*Leptodactylus fallax*) [Jennifer C. Daltry and Gerard Gray]; Amphibian Breeding and Climate Change [Tim Halliday]; Ohio Working Group Meeting Report [Jeffrey G. Davis]; Amphibian Disease Website [Lee Berger - http:/www.jcu.edu.au/school/phtm/PHTM/frogs/ampdis.htm]; The UK Pool Frog Species Action Plan [Tony Gent]; Froglog Shorts; Publications of Interest.

Froglog is available from Editor John W. Wilkinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk

FRANCIS R. COOK

Errata, *The Canadian Field-Naturalist* 113(1): A Passion for Wildlife

Photo captions
Photo, page 33
Vic Solman

Photo, page 43
... on Ellesmere Island, NWT, in 1971.

Photo, page 107
... Barbara Campbell, (r.), and Lynne Allen

Back cover
The image of Don Reid, banding Thick-billed Murres on Coburg Island, Northwest Territories, ...

Text
page 38
Hans Blokpoel, biologist and former ornithologist in the air force of the Netherlands, ...

Page 79, note 85
Musk-ox Lake

Page 120
The two concluding paragraphs were inadvertently omitted in the proofs:

Closer consultation on topics of ever-broadening scope appeared to be a dominant theme for CWS at this time. Issues such as acid rain, endangered species, and a national habitat strategy all demonstrated the necessity of this approach, as did extensive discussions of how to devise a new National Wildlife Policy for Canada. A draft policy was tabled at the 1980 Federal-Provincial Conference, but it would be some time before consensus could be reached on a matter in which so many details crossed federal and provincial jurisdictional lines (see Chapter 10).

The years 1977–1982 were challenging for the Wildlife Service, but produced valuable models for future cooperation in wildlife and environmental management and policy development. Unfortunately, Alan Loughrey, a man with a keen appreciation for the subtleties of policy as well as the practical experience of an old Arctic hand, was unable to enjoy the accomplishments of the period in full measure. A serious and protracted illness led to his early retirement in 1981. He was succeeded in the position of Director General by Bert Tétrault, formerly Director of Wildlife Research with Quebec's Ministère du Tourisme, de la Chasse et de la Pêche.

PAT LOGAN

Canadian Wildlife Service, Environment Canada, Ottawa K1A 0H3

Minutes of the 120th Annual Business Meeting of The Ottawa Field-Naturalists' Club, 12 January 1999

Place and Time: Canadian Museum of Nature, Ottawa, Ontario, 7:30 p.m.
Chairperson: Dave Moore, President
Attendance: Twenty-nine persons attended the meeting.

Attendees spent the first half hour reviewing the minutes of the previous meeting, the Treasurer's Report and the Reports of Committees. The meeting was called to order at 8:00 p.m.

1. **Minutes of the Previous Meeting**

Moved by Bev McBride (2nd by Ellaine Dickson) that the minutes be accepted.

(Motion Carried)

2. **Business Arising from the Minutes**

There was no business arising from the minutes.

3. **Communications Relating to the Annual Business Meeting**

There were no communications relating to the Annual Business Meeting.

4. **Treasurer's Report**

Moved by Bill Cody (2nd by Philip Martin) that report be accepted subject to approval by the Auditor.

(Motion Carried)

5. **Committee Reports**

Dave introduced each of the reports and asked for comments and questions. Cheryl McJannet noted the Education & Lectures committee required new members to help with sales at the monthly club meetings. It was noted that Taverner was misspelled in both the Birds Committee and Fletcher Wildlife Garden Committee reports. Stephen Darbyshire pointed out that the word Club was omitted from the Macoun Field Club Committee report. Dave Moore noted that Dave Smythe's name needed to be added to the report of the Membership Committee.

It was moved by Chris Traynor (2nd by Cheryl McJannet) that the Committee Reports as amended be accepted.

(Motion Carried)

6. **Nomination of the Auditor**

Colin Gaskell reported that since no volunteers came forward for the Treasurer's position, the Finance Committee intended to recommend to Council that the Auditor be contracted to perform these duties. It was moved by Colin Gaskell (2nd by Bill Cody) that Janet Gehr continue as Auditor for another year.

(Motion Carried)

7. **Report of the Nominating Committee**

Colin Gaskell reported that there were no nominations forthcoming from notices placed in *The Canadian Field-Naturalist* and *Trail & Landscape*. The Committee recommended the following list of candidates for the 1999 Council (new members are indicated by an asterisk):

President	Dave Moore
Vice -President	David Smythe
Vice -President	Eleanor Zurbrigg
Recording Secretary	Garry McNulty
Corresponding Secretary	(obsolete position)
Treasurer	(vacant)

Ronald Bedford	Anthony Halliday
Colin Bowen*	David Hobden*
Michael Brandreth	John Martens*
Fenja Brodo	Philip Martin
William Cody	Cheryl McJannet
Francis Cook	Frank Pope
Ellaine Dickson	Stanley Rosenbaum
Barbara Gaertner	Dorothy Whyte

Six members of the 1998 Council decided not to stand for re-election: Stephen Bridgett, Alan German, Jeffery Harrison, Isabelle Nicol, Simon Shaw, and Chris Traynor. Colin thanked all of these members for their contributions to the 1998 Council.

It was moved by Colin Gaskell (2nd by Eleanor Zurbrigg) that the proposed slate be accepted.

(Motion Carried)

7. **New Business**

Stephen Darbyshire explained that Public Works had recently revoked the club's warehouse privileges at the Experimental Farm where back issues of both the CF-N and T&L were housed. However, thanks to a lot of work by Bill Cody, this problem has been taken care of.

Dave Moore expressed his appreciation for Bill's efforts in seeing that the warehouse was cleared out as requested by Public Works.

8. **Presentation by the Computer Management Committee**

Alan German gave a presentation of the Club's award winning web site and all the latest features available to members and non-members who surf the net. It was noted that new members are joining the club while others are making purchases of club merchandise after having visited the site.

9. **Adjournment**

Moved by Alan German (2nd P. Martin) that the meeting be adjourned at 8:55 p.m.

(Motion Carried)

Dave Moore invited members to have some coffee.

GARRY MCNULTY
Recording Secretary

Committee Reports for 1998 to The Ottawa Field-Naturalists' Club

Awards Committee

The following awards for 1997 were presented at the Annual Soirée held on 24 April 1998;

MEMBER OF THE YEAR AWARD. Eileen Evans for her many contributions to the club including, articles to *Trail & Landscape*, leading walks, serving on committees and especially her contributions to the annual soirée and monthly meetings.

ANNE HANES NATURAL HISTORY AWARD. Joyce and Allan Reddoch for their 20 plus year study on the orchids of the Ottawa district which appeared in the January–March 1997 issue of *The Canadian Field-Naturalist*.

CONSERVATION AWARD FOR MEMBER. Mike Runtz for his contributions for the protection of sensitive areas within Algonquin Park, the Stewartville Bog, Gillies' Grove and other wild places. Also of note were his many books popularizing nature and promoting conservation.

CONSERVATION AWARD FOR NON-MEMBER. The Natural Heritage Information Centre for the documentation and preservation of Ontario's natural history.

GEORGE MCGEE SERVICE AWARD. Bernie Ladouceur for his many years of service on the Bird Committee, the Christmas Bird Count, leadership on excursions and his involvement in the Birding Challenge Contest for area school children.

HONORARY MEMBER. John Livingston for his outstanding contributions as an academic and popular educator and philosopher in environmental science.

SPECIAL RECEPTION. In recognition for his 50-year anniversary as council member and business manager of *The Canadian Field-Naturalist*, a special reception was held for Bill Cody. This unprecedented dedication and service required special recognition and appreciation.

STEPHEN DARBYSHIRE

Birds Committee

The committee continued its regular activities such as, the Fall and Christmas bird counts, maintaining the Bird Status Line and The Rare Bird Alert and the operation of club bird feeders through funds raised by the seedathon. The committee also participated both as organizers and competitors in the Taverner Cup birding challenge. Members continued to review rare bird reports and organized several lectures to help improve birding skills of club members.

Again this year the committee participated with the Ontario Ministry of Natural Resources in the Peregrine Falcon Watch and also held their second birding challenge for area school children in May.

CHRIS TRAYNOR

Computer Management Committee

The desktop publishing software used to produce *Trail & Landscape* was updated to provide greater compatibility with the hardware system now in use and to facilitate the transfer of electronic files in formats used by the editor of *The Canadian Field-Naturalist* which will also require upgrading of some of the associated hardware.

Work continued on the further development and enhancement of the club's award winning web site. Usage of the web site increased substantially over the past year. A number of individuals joined the OFNC as a result of reviewing the web site while other non-members purchased club publications listed on the site. One item of special interest was the site's daily coverage of the Peregrine Falcons which nested on the roof of the Citadel Inn. Several club members contributed sightings to our Peregrine Watch web page. More recently, a virtual tour of the Fletcher Wildlife Garden has been added to the site. This features digital photographs of the different habitats in the garden with associated textual descriptions.

ALAN GERMAN

Conservation Committee

The committee drafted and reports and spoke on several conservation issues including the following:

1) Watts Creek Water Park
2) Montfort Woods
3) Endangered Species Legislation
4) Lands for Life
5) Petrie Island
6) Gillies' Grove
7) Spring Bear Hunt

To achieve more influence, the committee also established links with Environmental Advisory Committees in

Gloucester, Gouldbourn, Nepean, West Carleton and Ottawa.

STAN ROSENBAUM

Education & Publicity Committee

The committee made presentations on birds, bird feeding, bird banding and nature walks at several venues including the Lakeside Gardens Recreation Center, Ashbury College, Bells Corner Public School, Scouts Canada, Confederation High School and Bells Corner United Church.

Members of the committee acted as judges at the annual Ottawa Science Fair while others helped promote the OFNC at the Carleton Teachers' Federation PD Day and during Wildlife Week. The committee also raised funds for the Alfred Bog and the OFNC by way of sales of club merchandise.

CHERYL MCJANNET

Excursions & Lectures Committee

The committee made arrangements for 45 outings in 1988 to study a wide range of subjects including birds, plants, insects, amphibians, fish, geology and astronomy. In addition, the committee also held nine monthly meetings at the Canadian Museum of Nature plus three workshops on the identification of sparrows (lbj's) and gulls, The annual trips to Presqu'île and Derby Hill were well attended and continue to be very popular club trips. The club's Annual Soirée was held at the end of April.

PHILIP MARTIN

Executive Committee

The committee met twice in 1998, once to discuss the new postal rates and probable loss of our mailing subsidy, an issue yet to be resolved, and again to discuss the club's budget and the possibility of rate increases to members and subscribers. The committee also conducted a combined e-mail and telephone meeting to approve funds relating to Lands for Life.

DAVE MOORE

Finance Committee

The committee met three times in 1998. An unaudited version of the Financial Statement for 1996-97 was accepted by Council at its January meeting and was presented to members at the annual business meeting. The result of the subsequent audit resulted in no change to the statements presented. Faced with potentially higher postal rates, the committee recommended an increase in fees and subscriptions and these proposals were agreed to by Council in June. A draft budget for 1998-99 was presented to Council in September and accepted in October after adjustments. The budget for 1998-99 aims at break even for both the OFNC and CFN accounts.

ANTHONY HALLIDAY

Fletcher Wildlife Garden Committee

Approximately 3000 volunteer hours were contributed this year and ten special events were held that brought out over 200 visitors while a dozen slides talks were given to horticulture and natural history organizations in the Ottawa Valley. The main focus this year was on the Backyard Garden but all habitats were improved and many enhancements were added including new birdboxes. Damage in the Ash Woodlot from the ice storm required special effort as did the attempt to control Swallowwort in all habitats. New species of frogs, turtles, butterflies and birds were recorded in the garden. Funding exceeded expenditures thanks to the Taverner Cup, a garage sale and a $3000 donation from Landscape Ontario and Canada Blooms. New pamphlets, trail guides and a general brochure were published and four FWG newsletters were issued.

PETER HALL

Macoun Field Club Committee

The committee met five times during the year to plan the week-to-week program for the children and young people of the club. Former members and leaders spanning the club's entire history were invited to a celebration of the Macoun Club's 50th anniversary held in June. At a subsequent meeting, both the President of the OFNC and the Director of the Canadian Museum of Nature reaffirmed their commitment to the continuing operation of the club.

ROBERT E. LEE

Membership Committee

The distribution of memberships for 1998 is shown in the table (below), with the comparable numbers for 1997 in brackets.

	CANADIAN		FOREIGN		
Type	Local	Other	USA	Other	Total
Family	352 (346)	23 (20)	2 (4)	1 (0)	378 (370)
Individual	364 (371)	131 (132)	24 (23)	3 (3)	522 (529)
Honorary	14 (13)	9 (10)	0 (0)	0 (0)	23 (23)
Life	16 (16)	20 (19)	4 (4)	1 (2)	41 (41)
Sustaining	9 (10)	0 (2)	0 (0)	0 (0)	9 (12)
Total	755 (756)	183 (183)	30 (31)	5 (5)	973 (975)

Note: Does not include individual and institutional subscriptions.

These statistics do not include the two complimentary memberships awarded annually to winners in the Science Fair competition nor the 15 affiliate organizations which receive copies of the club's publications.

This year the club awarded an Honourary Membership to John A. Livingston, an academic and popular educator and philosopher in environmental sciences.

The club will miss several long time and active members who died in 1998, Dr. Loris S. Russell, a member since 1933 and Member of the year in 1997, and Lois Cody, a member since 1951 and the Treasurer's Assistant for many years.

DAVE SMYTHE

Publications Committee

The committee met twice in 1998. Three issues of *The Canadian Field-Naturalist* were published in 1998 containing 598 pages, 48 articles, 29 notes, 9 COSEWIC articles, 51 books review, 224 new titles, 2 commemorative tributes and 33 pages of News and Comments. The CFN remains up to date and since 1976 has made a profit in all but three years when special issues were published.

Volume 32 of *Trail & Landscape* was published in 4 issues that contained 200 pages. Birds, flora and conservation issues were the three most common topics.

The club lost its storage privileges with Public Works Canada in November necessitating the discard of a large number of back issues of the two journals.

RONALD E. BEDFORD

The Ottawa Field-Naturalists' Club Financial Statements

for the year ended 30 September, 1998

Auditor's Report

To: The Members of THE OTTAWA FIELD-NATURALISTS' CLUB:

I have audited the balance sheet of The Ottawa Field-Naturalists' Club as at September 30, 1998, the statement of changes in net assets, and the statements of operations. These financial statements are the responsibility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, the Ottawa Field-Naturalists' Club derives some of its revenue from memberships, donations, and fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the organization.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenues referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the OFNC as at September 30, 1998, and the results of its operations and changes in net assets for the year then ended in accordance with generally accepted accounting principles.

JANET M. GEHR, C.A.
Chartered Accountant

North Gower, Ontario
February 8, 1999

The Ottawa Field-Naturalists' Club
Balance Sheet
September 30, 1998

	1998	1997
ASSETS		
CURRENT ASSETS		
Cash	$ 17,344	$ 10,035
Marketable securities	178,277	195,857
Accounts receivable	10,933	16,264
Prepaid expenses	1,000	1,608
	207,554	223,764
CAPITAL ASSETS	-	-
LAND - Alfred Bog	3,348	3,348
	$210,902	$227,112

LIABILITIES AND FUND BALANCES

	1998	1997
CURRENT		
Accounts payable and accrued liabilities	$ 13,996	$ 14,000
Deferred revenue	11,303	12,361
	25,299	26,361
LIFE MEMBERSHIPS	7,475	7,475
	32,774	33,836
NET ASSETS		
Club reserve	$100,000	$100,000
Seedathon	1,378	1,405
Ann Hanes memorial	870	10,035
de Kiriline-Lawrence	27,221	21,892
Alfred bog	495	531
Unrestricted	48,164	68,578
	178,128	193,276
	$210,902	$2 ,112

The Ottawa Field-Naturalists' Club
Statement of Operations - OFNC
Year Ended September 30, 1998

	1998	1997
REVENUE		
Memberships	$ 13,242	$ 13,667
Trail & Landscape subscriptions and back issues	233	274
Interest	1,670	1,501
Other sales	-	779
Special publications	68	-
	15,213	16,221
EXPENSES		
OPERATIONS EXPENSES		
Affiliation fees	675	1,104
Computer	841	3,026
Membership	160	79
Office assistant	1,417	1,333
Operations	6,217	5,515
OFNC GST Rebate	1,455	2,309
	10,765	13,366
CLUB ACTIVITY EXPENSES (Income) - Net		
Awards	411	463
Soiree	166	534
Birds	269	663
Conservation	547	-
Education and publicity	144	615
Excursions and lectures (Note 4)	(541)	(1,111)
Fletcher Wildlife Garden (Note 5)	825	(3,459)
Macoun club	1,101	1,209
Trail & Landscape	7,260	10,328
	10,182	9,242
	20,947	22,608
DEFICIENCY OF REVENUES OVER EXPENSES	$ (5,734)	$ (6,387)

The Ottawa Field-Naturalists' Club
Statement of Operations - CFN
Year Ended September 30, 1996

	1998	1997
REVENUE		
Memberships	$ 8,815	9,603
Subscriptions	24,210	25,278
	33,025	34,881
Reprints	5,850	10,034
Publications	25,071	24,954
Back numbers	-	20
Interest and exchange	10,889	8,465
Donations	-	450
	41,810	43,923
	74,835	78,804
EXPENSES		
Publishing	58,765	81,643
Reprints	6,123	7,609
Circulation	5,134	7,714
Editing	2,852	3,336
Office assistant	4,583	4,667
Office supplies	1,161	1,791
Honoraria	6,000	6,300
CFN GST Rebate	4,897	6,487
	89,515	119,547
DEFICIENCY OF REVENUES OVER EXPENSES	$(14,680)	$(40,743)

Note: A more detailed financial statement is available to any member who wishes to contact the Club.

Book Reviews

Zoology

Butterflies of the World

By Sbordoni, V. and S. Forestiero. 1998. Second edition. Firefly Books Ltd., Willowdale, Ontario. 312 pages.

This second English edition of *Butterflies of the World* is exactly the same as the first English edition of 1985. The book was originally written in Italian and published in 1984. In the modern English literature on Lepidoptera, this book is incomparable by the coupling of its very abundant and beautiful color iconography and the wide variety of subjects it covers. The title does not correctly represent the contents as it implies that all of the species of butterflies are included, and also because moths are treated extensively; more appropriately the book could have been titled *The world of butterflies and moths*. The main drawbacks of the work are that several sections are outdated and some others contain many small to major editorial flaws, which could have easily been taken care of in this second edition.

After a foreword and preface, the text opens with a section on the structure, origin, and relationships of butterflies and moths, unfortunately containing detailed illustrations only for adults, and which could have been improved by a different labeling system.

The second chapter, on the life cycle, shows plates with a diversity of eggs, larvae, and pupae, as well as the complete life cycle of *Papilio xuthus*. There is some contrast in the quality of the plates, the colors on some being more vivid than on others (compare plates 5 and 6 for example).

The third chapter starts with a section on the kinds of diversity (within species, within genera, and within the order), followed by another on genetics and the bases for the changes leading to the appearance of new forms through natural selection. This is accompanied by smaller sections describing several kinds of variability within species (sexual dimorphism, seasonal variation, variation caused by pollution, etc.).

The fourth chapter is a detailed 20-page discussion on the mechanisms behind the formation of new species, with many examples mostly taken from the European fauna.

The fifth chapter explains the science of systematics, and the many activities which are part of it: phylogenetics, classification, taxonomy, and nomenclature. The authors also discuss taxonomic characters and character states, but their discussion of molecular characters omits many of them, such as nucleic acids' analysis of fragments, restriction sites, and sequences, which have become very important in systematics in the past decade.

A systematic survey of the families of Lepidoptera makes up the sixth chapter. Although the classification and phylogeny adopted are outdated, almost all currently recognized families are included. It is in this chapter that I found the most problems in the style of the writing, its quality (there are many typographical errors), and the scientific accuracy. For example, let us examine what the authors have written concerning the Pyralidae, a group on which I have a better research expertise than others. The authors mention that I.F.B. Common recognizes five families in the Pyraloidea; this was true in 1970, but he recognizes only one in his book on the moths of Australia (1990). Later the authors discuss the Tineodidae and Oxychirotidae (spelled Oxychiotidae once), two families which are considered synonyms (under Tineodidae). We are told that the Pyralidae vary in size from 15 to 30 mm, while 10 to 100 mm would be more accurate, and that venation is usually absent in the hind wing! In the discussion of the Nymphulinae, *Parapoynx* is misspelled. In the discussion of Schoenobiinae, we find that there is a tuft of anal hairs in members of the genus *Scirpophaga*, while this is so in the females only; that *Acentropusis* [instead of *Acentropus*] *niveus* (now *Acentria nivea* in the Nymphulinae) is a European species, while it also occurs in North America; and that pyralids have the ability to breathe under water in different ways while only some Nymphulinae and Schoenobiinae have this ability! Within the section on Phycitinae we are told that this group contains many tens of thousands of species, while there are currently no more than 25 to 30 thousand described species in the family Pyralidae (in the 20 subfamilies it contains); and the name *Ephestia kuehniella* is misspelled. If we look at the section on the Pterophoridae we find, among a few problems, that the authors write incorrectly that *Agdistis* and *Pterophorus* have no spurs on their legs, and that larvae feed on grasses (they feed on Asteraceae and Plumbaginaceae, and on Convolvulaceae, respectively).

The following four chapters cover the topics of behavior, population fluctuations, migrations, many aspects of the ecology of Lepidoptera, including mimicry and other strategies of defense against predators, with a broad range of well-illustrated examples.

Then follows a chapter where aspects of community ecology are treated, with examples of Lepidoptera communities in the most important biomes of the earth. This is followed by a chapter on zoogeography, where the authors characterize geographical ranges, examine the processes influencing distributions, and discuss the six biogeographic regions, presenting typical examples of their lepidopteran, especially butterfly, diversity.

Then a short chapter entitled "Butterflies and Man" discusses a few species of moths... harmful to human activities, such as the gypsy moth, useful ones that are eaten by various groups of people or used in weed management, and what Lepidoptera represent culturally in various human societies.

The last three chapters are devoted to the classification of Lepidoptera, how to collect, breed and preserve them, and issues regarding their conservation and that of their environment. The chapter on classification is mostly an historical overview of the major improvements of the classification through time, which I believe would have been best incorporated within the fifth chapter. In the section on collecting nocturnal species, the authors mention that the females of some species emit infrared rays, and that males have the ability to detect those, which is why they are attracted to light more than females! I find this highly suspicious, since I have never seen mention of infrared emitting females anywhere else (it would be a major discovery to say the least!) and moreover, moths are best attracted by ultraviolet emissions. In the section on collecting microlepidoptera, as opposed to what the authors say, specimens should be anesthetized only just before spreading, ammonia vapors are best used for that purpose as they help maintain the specimens soft, and the moths can be spread just like macro moths on appropriate setting boards (made of plastazote) with pieces of transparent paper maintained by minutens. Also, labels should have the year of collection written in full, as opposed to the last two digits only, and labels should not be made with a photocopier, as these have been shown not to last long enough. In the section on how to study genitalia and wings, the most common method of wing preparation, with the use of hypochlorous acid to discolor them and fuchsin acid to stain them, is not mentioned. Also, the authors recommend dehydrating the dissected genitalia by immersion in alcohol for a few hours at rising temperatures of 45, 75, 95 and 99°C. I think here the authors meant to immerse the genitalia in baths of ethyl alcohol of rising concentration, but at room temperature; at least this is the method I have seen described in several works and which I have been using successfully for years in making over 1500 slides.

Overall, I think this book would be useful to beginners to Lepidoptera, as no other available book covers so many aspects of the world of Lepidoptera with so many nice illustrations. However, the errors I have seen in the few sections I have looked at carefully, and the fact that several sections are outdated, should prevent anybody for using it for making any definite statement in any serious endeavor. For the latter purpose, the works of I.F.B. Common (*Moths of Australia*, Melbourne University Press, 1990) and M. J. Scoble (*The Lepidoptera; form, function and diversity*, Oxford University Press, 1992) among others, should be consulted.

BERNARD LANDRY

18 Washington Street, Aylmer, Québec J9H 4B9, Canada

Population Limitation in Birds

By Ian Newton. 1998. Academic Press, San Diego and London. 597 pp., illus. Can. $79.95.

The author of *Population Ecology of Raptors* and *The Sparrowhawk* and the editor of *Lifetime Reproduction of Birds* has done it again! Ian Newton's latest book is organized logically and sequentially, packed with information, and written "in simple language in the hope that it will be of value not only for the professional ecologist, but for anyone with an interest in birds." It is encyclopedic, an open sesame to the world's bird population literature. A tour de force.

Every reader will appreciate Newton's attention to fundamental principles, illustrated by detailed examples. The extent of his scholarship is evident from the 75-page bibliography, which summarizes the important new advances in knowledge since David Lack's 1954 classic, *The Natural Regulation of Animal Numbers*.

Newton's book is divided into three parts: Behaviour and Density Regulation (social systems and status; habitat and density regulation; territorial behaviour and density limitation; density-dependence; habitat fragments and metapopulations); Natural Limiting Factors (food-supply; nest-sites; predation; parasites and pathogens; weather; interspecific competition; interactions between different factors); and Human Impacts (hunting and pest control; pesticides and pollutants; extinction). These sixteen chapter headings indicate the main factors, individually and collectively, bearing on the regulation of bird populations. Indeed, the sixteen chapter summaries alone provide an ideal review of this broad topic.

The text is enhanced by 110 graphs. Fifty-eight tables summarize an enormous amount of pertinent information and are themselves an outstanding reference source.

How can I share any sense of this wealth of information? Let me offer a few examples of information new to me. Consider large bird numbers. Twenty million Bramblings have occupied a single roost in central Europe. A colony of Galapagos Storm Petrels packed 200 000 pairs into 2500 m^2, a mean density of 8 pairs per square meter. Tree Swallows reached a density of 150 pairs in one 0.3 ha meadow. Near New York a giant Purple Martin house contained over 250 pairs. A Cliff Swallow colony on a Wisconsin barn increased from one pair in 1904 to more than 2000 pairs in 1942, aided by House Sparrow control and by construction of shelves on the outside of the barn.

Consider mechanisms of population control. When species decline in numbers, careful research may show either a decline in survival rate but no change in reproduction (Golden Plover) or a decline in reproduction but no change in survival (Lapwing). Paradoxically, lowest weights of birds may occur in a time of plenty.

Consider the downside of recent changes in farm practice in England. Land-drainage results in drying and hardening of top soil, makes invertebrates less available and allows access by machinery earlier in the year; the result, inadequate production of Lapwing chicks. Lapwing hatch success was much lower when early haying occurred and when more animals were pastured.

Consider predation. With prey-controlled dynamics, the numbers of prey, e.g. Snowshoe Hares, influence the numbers of predators but not vice versa. With predator-controlled dynamics, the numbers of predators influence the numbers of prey, e.g., ducks, but not vice versa.

Consider parasites. A tick, *Ornithodoros*, may decrease Prairie Falcon chick survival by 65%; a Fly, *Eusimulium*, may decrease Red-tailed Hawk chick survival by 24%. In Hawaii, the indigenous birds are restricted to high and dry areas, whereas birds below 1500 m elevation are almost all introduced species, resistant to avian malaria and avian pox, carried by mosquitoes which were first introduced in 1826.

Within this book are probably another thousand examples, many of equal interest or greater importance, difficult to convey in a brief review. Suffice it to say that this book, as promised, gives "a sound basis both for further research and for more effective management." Every college library should have one or more copies. I recommend it without reservation.

C. STUART HOUSTON

863 University Drive, Saskatoon, Saskatchewan S7N 0J8, Canada

Herpetology

By F. Harvey Pough, Robin M. Andrews, John E. Cadle, Martha L. Crump, Alan Savitzky, and Kentwood D. Wells. 1998. Prentice-Hall, Upper Saddle River, New Jersey. xi + 577 pp., illus., U.S. $39.95.

Yet another overview of herpetology? We seem to be getting a new text at least once every other year (see reviews of *Herpetology: An introductory biology of amphibians and reptiles* (1993), reviewed in *The Canadian Field-Naturalist* 109(4):483–485, *Amphibian biology* (1995) in *CFN* 111(4): 467–489; *A natural history of amphibians* (1995) in *CFN* 112(2): 374–375) attesting to the high profile that reptiles, and especially the problematically declining amphibians, have achieved in the 1990s.

But this volume contrasts with previous efforts which have been either the product of one or two authors or a collection of individual contributions edited by two joint editors. Here we have a seamlessly unified collaboration of six prominent active researchers, all with practical university teaching experience. It attempts to interweave their individual specialities of autecology, synecology, evolution, morphology, physiology, and behaviour throughout.

The book is in four major parts with varying numbers of chapters: What are amphibians and reptiles? (Herpetology as a Field of Study, The Place Amphibians and Reptiles in Vertebrate Evolution, Classification and Diversity of Extant Amphibians, Classification and Diversity of Extant Reptiles); How do they work? (Temperature and Water Relations, Energetics and Performance, Reproduction and Life History, Body Support and Locomotion, Feeding); What do they do? (Movements and Orientation, Communication, Mating Systems and Sexual Selection, Foraging Ecology and Interspecific Interactions, Species Assemblages); and What are their prospects for survival? (Conservation and the Future of Amphibians and Reptiles). There is a 52-page bibliography: all but a very select few of these citations are from the 1970s, 1980s, and 1990s.

The authors carefully note in their introduction that this is intended as a textbook not a reference book. The distinction here is that the topics are covered for interest and relevance but are not necessarily comprehensive and the text flows like a lecture with authorities inserted where most needed, but not for every statement. Most users will find it, however, far more than adequately exhaustive on virtually any topic. Each chapter concludes, textbook style, with a brief summary of its important points.

Adequate discussion by chapter might fill this issue by itself, but a couple of interesting updates to note are that birds (pegged at approximately 8700 species) are now routinely included as Reptilia in the discussion of classification (page 75) but the book nonetheless confines itself to the traditional approach to reptiles in detailing the classification only of the 7132 non-birds (turtles 260 species, crocodilians 22, and squamates 6850 - lizards, snakes and amphisbaenians). Totals now for amphibians are 4680 species: 4100 frogs, 415 salamanders, and 165 caecilians. In the discussions of their classification there are a few very useful references for each family to provide a entrance via the most recent to the increasingly volumous systematic literature of the past 240 years.

The concluding chapter is most sobering. Responsibility for the world biodiversity decline is squarely laid in large part to human activity. Against the discouragement of the chronical of known declines and extinctions, the authors place the efforts made by scientists and nonscientists alike toward the conservation of amphibians and reptiles and claim that hope exists, They argue for the importance of considering the needs of local people and providing economic incentives for preserving both habitat and sustainable populations. And they emphasize that although habitat preservation is the most important action to be taken, there is need for more research on the habitat requirements. reproductive biology, life history characteristics, dietary needs, and genetic diversity of threatened and endangered species. With texts as through and stimulating as this for a basis, dare we hope that the generation of herpetologists about to be in-training will find and apply blocks to extinction? Or will the human economic appetite be checked only by consumption of all resources no matter how many or how erudite the studies that are reported?

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Amphibians in Decline: Canadian Studies of a Global Problem

Edited by David M. Green. 1997. Society for the Study of Amphibians and Reptiles, Herpetological Conservation Number 1. xii + 338 pages, illus., $55.

Since it crystallized at the First World Congress of Herpetology in 1989, concern for declining amphibian populations has steadily accelerated. Generated by this was an interantional Decline in Amphibian Populations Task Force (DAPTF). A Canadian component (DAPCAN) was organized from a meeting at Burlington, Ontario, under the auspices of the Canadian Wildlife Service in the fall of 1991. It has since met annually at a different local from Nova Scotia to British Columbia. Interestingly, Canada, with only 1% of the world's amphibian and reptile species, has been a world leader in organization and variety of research projects on possible declines. A potpourri of active researchers applied themselves to the subject from museums, universities, provincial wildlife/environment departments, the Canadian Wildlife Service, various societies, and interested individual naturalists who have responded to a variety of provincial monitoring and atlassing projects.

Now comes a new book which is a worthy advance over the initial volume of DAPCAN discussions and abstracts published following the first meetings, *Declines in Canadian Amphibian Populations: Designing a National Monitoring Strategy* (Edited by C. A. Bishop and K. E. Pettit. 1992. Canadian Wildlife Service, Occasional Paper Number 76. 120 pages). Some authors and key studies are the same in both volumes but those of the latter repeated have been updated, refined, expanded, and reviewed, often with several subsequent years of field work included. In the new volume, 29 chapters contain 31 submissions from 53 contributors who represent a virtual who's who of Canadian amphibian herpetologists including those who first focused on declines. In addition, there is an appendix in which Wayne Weller and David Green construct a new checklist of Canadian amphibian species, and another listing coordinators of DAPCAN past and present.

The research contributions range from monitoring genetic diversity in ambystomid salamanders in Ontario (Leslie Rye and colleagues from Jim Bogart's legendary team at Guelph) to mapping the distribution and abundance of the northernmost frogs of the Yukon (Lee Mennell) and Northwest Territories (Michael Fournier); from a larval perspective on monitoring populations (Richard Wassersug) to diseases in Canadian populations (Graham Crawshaw). The book is based primarily on papers first presented at DAPCAN meetings up to 1994 with additional pertinent contributions and solicited papers that were not part of any of the meetings. Because of the cutoff point, there is often a lack of recent references although the editor has been able insert a scatted few right up to 1997, mainly from his own work in press at the time (such as the defining of the latest new Canadian frog, *Rana luteiventris*, split primarily through molecular analysis from the formerly conglomerate *Rana pretiosa*). Justified by allusions to unreviewed (unpublished) studies or personal communication are species status for both *Bufo hemiophrys* and

Bufo fowleri, to align them with current evolutionary species concepts.

Editing contributions from so many authors with such varying backgrounds and sophistication, particularly against a deadline, must have been a horrific task, and some lapses are hardly surprising. Examples include the article by Lepage, Courtois and Daigle where the Deciduous and Mixed zones supposedly depicted in Figure 1, page 129, are indistinguishablely white. A computerized text glitch missed by proofreading occurs on page 132 where sentences end in the fragments "simi" and decidu". The abstract of Green's own article on perspectives contains the redundant gem "Population changes are influenced by local conditions that ... are ... local." On page 316 a text account uses "*Spea intermontanus*" while the accompanying picture is labelled "*Spea intermontana*".

The pity is that this volume, so clearly celebrating Canadian successes, had to look to an American herpetological society for publication. Regardless, it is a watershed, effectively concluding the first stage of the Canadian initiative. Green has already moved from chairing DAPCAN to other challenges, becoming co-chair amphibians and reptiles for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and subsequently chairman of COSEWIC itself. DAPCAN has metamorphosed under its new chair, Stan Orchard, to add study of reptile survival as the Canadian Amphibian and Reptile Conservation Network.

This volume is a credit to the dedication of its editor, to its many participating reviewers, and to zeal of the authors who responded. It will be a model and a jumping-off point (if I may be pardoned the phrase) for both world and future Canadian amphibian studies on the growing variety of possible causes underlying postulated declines.

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Raptors of Arizona

Richard L. Glinski. 1998. University of Arizona Press, Tucson. 220 pp., illus. U.S. $75.00.

What a wonderful concept! Create a book devoted exclusively to the raptors of one state and have a fine artist make full-page colour paintings of each. Choose a state with "a blend of raptor habitats equal to any on earth," and emphasize the unique specialization of each species. Provide succinct, well-written accounts by 27 individual experts who have studied that species, and offer interesting new data that allows the reader to have "smelled the smoke from their campfires," as Clayton White's foreword says. Edit the material so expertly that it reads as though written by the same person. All of this has been achieved.

The 42 full-page colour paintings by Richard Sloan, emphasizing the habitat of each species, will give many persons sufficient motivation to purchase this rather expensive book. The paintings are aesthetically pleasing, but not very useful for identification purposes: with four exceptions, only one perched adult is depicted, the bird is often rather small, and only the Condors are shown in flight. Each legend gives only the species name, and does not identify the locality or name the trees; the presence of the platform in the caracara painting is not explained.

Etiquette of raptor watching is emphasized. One is advised to observe open-country nests from a distance of at least half a mile!

Interesting snippets of information abound. The Black Vulture gobbles down its food with extreme rapidity; sudden arrivals of Turkey Vultures in autumn are termed "frost flights"; California Condor females plop their egg from a standing position onto a cushion of litter in the nest, so that the egg does not break; cattle dung has been found in Osprey nests; young White-tailed Kites establish their own territories four months after their first flight; the Mississippi Kite loops and rolls after insects in flight; Bald Eagle nestlings may die from heat stress and from attacks by blood-sucking Mexican chicken bugs; the Sharp-shinned Hawk may nest very close to an active nest of the Northern Goshawk; the Common Black-Hawk preys on fish and frogs in streams less than eight inches deep; Harris' Hawks inhabit desert but seem to require presence of cattle ponds; mesquite bosques are necessary for the Gray Hawk, yet vast areas of mesquite have been cleared for alfalfa pastures; Zone-tailed Hawks usually nest within a mile of a Turkey Vulture roost and seem to use their similarity to vultures to gain close approach to prey habituated to presence of harmless vultures; Crested Caracaras usually nest in saguaro cacti; Barn Owls may excavate a nest burrow up to 6 feet horizontally into a vertical soil wall; Northern Pygmy-Owls may attack prey twice their weight; the Spotted Owl ambushes rather than pursues its prey.

I found it interesting that Prairie Falcons in Arizona prefer north-facing cliffs, presumably for protection from the sun's heat, whereas in Saskatchewan they prefer south-facing cliffs to obtain benefit of the sun's warmth.

Statements concerning protection by the Migratory Bird Treaty are inconsistent between species. Only one species account, Glinski's own of the Golden Eagle, provides a full explanation. Raptors have been protected under the treaty only since 1972 amendments were made by the United States and Mexico, without participation by the initial 1917 signatory, Canada.

Sadly, distribution maps are detailed for some but disappointing for about half the species; a few contradict the text. Nowhere is there a map of the 16 biotic communities, including four varieties of wetlands, nor are the counties nor all the villages mentioned in the text located on the map. Altitudes, so crucial to distribution in a mountain state, are not mapped. Hence one is forced to use an up-to-date Arizona highways map to follow the text. Indeed, the text rarely uses biotic communities as a means of describing distribution of individual species.

Estimates of state populations are provided for only 7 of the 42 species, although the number of sites occupied is offered for 9 others. Some statements are inadequately documented. Great Horned Owls have nested 98 feet apart, and nests in the Sonoran desert contain up to six Great Horned Owl nestlings, yet these two world records are not documented as to date or exact locality. No date or locality is provided for the only Saw-whet Owl nest record for Arizona. Apart from Snyder's account of the Sharp-shinned Hawk, subspecies are treated idiosyncratically. Dick Clark's study area near Delta, Manitoba, was not at the northern fringe of the Short-eared Owl range.

Do not let the price deter you. This is a worthwhile book!

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Amphibians and Reptiles of the Great Lakes Region

By James H. Harding. 1997. The University of Michigan Press, Ann Arbor, Michigan. xvi + 378 pp. U.S.$19.95.

Animal or plant guides are generally restricted to a country or a state/province within it, though many have railed against this "unnatural" approach and argued for an ecological unit or topographical area as a better choice. Funding, however, for both research and publication is most often available for political regions, and this has been the greater logic. But the previously geopolitically-biased data is extensive enough to allow pooling by natural geographical areas, and this book is a splendid example of what now is possible. In choosing the Great Lakes basin, this book straddles the United States and Canada and includes nearly all of the state of Michigan and portions of Ohio, Indiana, Illinois, Wisconsin, Minnesota, New York, and much of southern Ontario. (Note, however, that it is a Michigan produced book, and most of the state of Michigan just happens to conveniently fit into the Great Lakes area as defined).

Following the well-established pattern for guides, its bulk is species-by-species accounts. These are preceded by introductory material on using the book and summarizing some of the salient features of animals as a group, including place in the ecosystem, interactions with humans, and conservation, as well as the effects of past glaciation on the species composition and current distribution. The book concludes with a very useful resources section including a bibliography and information sources, listing of recordings of anuran vocalizations, of herpetological organizations, and of state and provincial regulatory agencies, and finally, a glossary of terms. Of these, the list of organizations most strongly reflects an American bias, no Canadian groups, neither the Canadian Association of Herpetologists nor the Canadian Amphibian and Reptile Conservation Network both of which have active members in the region, are mentioned. Some individual Canadian herpetologists are acknowledged as being consulted however, among them Craig Campbell, Michael Oldham, Al Sandilands, and Frederick Schueler for unpublished distributional and biological data and Ronald Brooks, Bob Johnson, and Kenneth Storey for correspondence on biology and taxonomy. Canadian references are largely to the now-dated overviews of Cook, Froom, Johnson, and Logier, a management paper by Brooks and colleagues, but with the important Herpetofauna Summary for Ontario distributions produced by Michael Oldham, Wayne Weller, and Al Sandilands with the collaboration of a multitude of others, omitted. There is a sparse representation of primary research papers, most of the bibliography is to secondary sources: guides and group syntheses.

The species accounts follow the popular mindset that if you write for the public, you must omit virtually all sources, leaving to the more scholarly readers the detection of origins on their own. This aside, the accounts are readable and apparently comprehensive. They follow standard headings: Description, Confusing Species, Distribution and Status, Habitat and Ecology, Reproduction and Growth, Conservation. Each has a map of the area with the range indicated by a generous splash of bright blue. A few of the maps depict range additions that are undocumented. The Dusky Salamander range is depicted as including a generous portion of the western Niagara Peninsula and a lesser but significant amount for Spring Salamander, and tiny portions for the Mountain

Dusky and Slimy salamanders. The Box Turtle range includes the Windsor area. If correct, the Mountain Dusky and Slimy salamanders would be new provincial records, but these depictions are likely simply artifacts of imprecisely positioned overlay during printing. Records for the for the Slider in southwestern Ontario are depicted though the text correctly ascribes them to introductions (releases or escapes) but records of equally likely introductions of the Box Turtle are not mapped. There are accounts for 18 salamanders, 14 anurans (frogs and toads), 12 turtles, 4 lizards, and 22 snakes. These include pooled treatments for taxonomically difficult pairs of subspecies (or in a few cases, difficult to distinguish species) : the Red-spotted and Central newts; Western and Boreal chorus frogs; the Eastern and Cope's Gray treefrogs; Midland and Western painted turtles; Northern and Lake Erie water snakes; Common and Chicago garter snakes; Northern and Midland brown snakes; Northern Black and Blue racers. Accounts for Blue-spotted, Jefferson, Small-mouthed, and Tiger salamanders and of Butler's and Short-headed garter snakes are separate but localized hybridization is discussed. Full species status is given to Fowler's Toad and to the Eastern Fox Snake (with a separate account for the Western Fox Snake, although the latter two could have been pooled to be consistent with other treatments of problematic pairs). The accounts conclude with paragraphs on 10 Marginal and Questionable species.

The real beauty of the book is in its nearly half-page colour photographs for all species, both those with full accounts and the marginal and questionable forms. These are quite literally breath-taking, sharp and typical for each species. They are well worth the price of the book by themselves, and give it a place on every Ontario naturalist's shelf.

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Nightjars: A Guide to the Nightjars, Nighthawks, and their Relatives

By Nigel Cleere, illustrated by Dave Nurney. 1998. Yale University Press, New Haven, Connecticut. 317 pp., illus. U.S.$40.

This volume is the latest in a series of monographs on closely related bird groups or families which have been appearing under the imprint of a couple of publishers on each side of the Atlantic, although the books are British in origin and authorship. The format is similiar in each, with introductory sections providing a broad overview of the group in question, and the individual species accounts giving a concise summary of information on each species, with an emphasis on identification and distribution. The latter material appears again in summary form on the page facing the colour plate of bird.

Within the broad framework there seems to be much variation from volume to volume in the amount of detail supplied, especially in the introductory sections. The present monograph is one of the best in this regard, with 24 pages covering taxonomy, distribution, morphology, structure and mechanics [more than I ever wanted to know], plumages and moult, behaviour, and the fossil record. The individual species accounts range in length from a little under a page for the less well-known species to six pages for the European Nightjar. While much space is devoted to descriptions of plumage, voice, races, and other features beloved of birders, there are good, concise accounts of habits and breeding where this information is available.

This series has been hailed by birders but approached with some confusion by reviewers, who have had a hard time fitting the books into a neat "user" niche. There seems to be a sense that they fall between two stools, ranging from not providing enough information for the serious student to providing too much for the average birder. It is argued that the user will never carry these books into the field, far less take them on a trip, so what good are they?

To some extent this criticism is valid, but I think it underestimates the sheer amount of preparation that birders are prepared to undertake today. Birders are avid consumers of any and all information that can help them in the pursuit of a species, and even if the book remains intact [some will simply remove relevant sections] I can visualize exhaustive notes being made for use in the field. This is especially true for those visiting parts of the world where field guides are less reliable than here. In this regard the data on life history are not only interesting background, but in fact can be a significant help, particularly in a new area where everything is unfamiliar.

That said, how good are the identification sections of the book? The text certainly was accurate and complete for the species I am familiar with, but I was less happy with the plates [36 in all]. The layout is good, with each species shown seated, and in most cases with one or two additional images of the bird in flight. However, my overall impression was that the colours tended to be rather too light and have too much contrast, although nightjars are a tricky group to assess in this regard — how often does one see them sitting in good light? One error I did detect is that the outer primaries of the Lesser Nighthawk are shown as longer than the adjacent ones, when in fact the reverse is true, as noted correctly in the text. This character can give quite a different "look" to the wing as compared with the Common Nighthawk, and is a useful field mark. The maps accompanying each species account also have problems. In fact, none of the Canadian species' ranges are accurately portrayed, even given the small size of the maps, although again the text is correct!

These faults aside, this is an excellent volume that provides a comprehensive and generally accurate overview of the world's nightjars. It will be of especial value to the travelling birder, but also will be of interest to anyone wishing to become more familiar with this elusive group of birds.

A brief supplemental note may be in order. Readers may well be thinking that no book can hope to deal adequately with the one key element of nightjar identification; that of voice. The end of the book contains an announcement that a companion CD has been produced, *A Sound Guide to Nightjars and Related Birds*, compiled by Richard Ranft, and also available through Yale.

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Dinosaurs of Utah

By Frank DeCourten 1998. The University of Utah Press, Salt Lake City. xiv+330 pp., illus. U.S.$24.95.

There are many facets to the "dinosaur craze". The obvious is the commercialization by companies that, for the most part, don't give a hoot as the credibility of the information they are passing on. The lunch boxes, toys, clothes really reveal nothing as to the true wonderment of the past. Nor do they comprehend the diversity and richness of the past. In an attempt to bridge this dilemma of forsaken knowledge we have another dinosaurs-of-a-state book, this time from Frank DeCourten of Sierra College, California. *Dinosaurs of Utah* is another book that cashes in on the craze but at least one will walk away with more respect and knowledge of the past.

Utah is rich in its paleontological resources, which DeCourten does much justice to. While providing examples, the author is able to illustrate a number of current themes of dinosaur paleontology, paleogeography, and evolution. But before this begins, the obligatory "what is a dinosaur", fossil identification, and general evolution are sketched out. The remainder and bulk of the text are geochronological beginning with the late Triassic Period. The diverse array of fossil plants, amphibians, trace fossils, and the famed *Coelophysis*, the small carnivorous dinosaur, are touched upon.

Much of the paleofauna of Utah comes from the Jurassic Period. Particularly, the Morrison Formation which is known from several states, and "has produced literally tens of thousands of dinosaur bones." Many include the sauropods (*Apatosaurus* and their kin), stegosaurs, ankylosaurs, iguanodons, and theropods — both small and large. The early Cretaceous is a little less known but its story is "still unfolding" as scientists continue to dig away. Even so, it too has its own unique fauna, probably none more infamous than the voracious *Utahraptor*. The late Cretaceous is divided into marine and terrestrial faunas. Though no dinosaurs were truly aquatic, the marine sequence, a time when much of the interior of North America was submerged under water, does reveal its own archaic fauna in the way of plesiosaurs, the archetype of the Loch Ness beast, and piscivorous birds with teeth. On land, the last of the sauropods and hadrosaurs walk unknowingly to their end, finally succumbing to the biological consequences of an impact of a multi-kilometer wide meteor.

The text of *Dinosaurs of Utah* is clearly written and is followed by a valued glossary, though the book could have used a little more personality. In a time when a number of dinosaur books focus on the faunas found within political boundaries, something the dinosaurs knew nothing about, it is imperative that an angle, or a hook, be exploited - something to make the book different. The vague road-log approach is useful for any dinosaur enthusiast, and the 20 plates representing different biological and environmental moments in geological time are very attractive. It is regional in scope, yes, but the book has the tools for more general, wider discussions of the most popular entities of the Mesozoic.

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The Nuthatches

By Erik Matthysen, illustrated by David Quinn. 1998. T & A D Poyser, London, U.K. 315 pp., illus. U.S.$39.95.

Erik Matthysen is a Belgian ornithologist who has studied nuthatches for 15 years, concentrating primarily on the Eurasian Nuthatch, which was already the most intensively-studied species in the family. This interesting volume provides a valuable account of this work — both his own and that of others — and then reviews the biology of the other 23 species in the family, summarizing what is known about each, using the much more extensive account of the Eurasian bird to provide context.

After an 18-page chapter "introducing the Nuthatches" there are nine chapters, or about 60% of the text, on the Eurasian Nuthatch, covering topics ranging from taxonomy and morphology to population dynamics, but with main emphasis on behaviour. These are followed by four chapters [some 30% of the text] on the rest of the family. The book concludes with six appendices covering such matters as scientific and common names, diagnostic traits and further statistics on the Eurasian Nuthatch. There are 28 pages of references and a short index.

My first reaction to the book was one of mild disappointment, feeling that the title was rather misleading. This sense was reinforced by the lack of a full range of illustrations of the species covered. The only colour plate is inside the front cover [it's not even listed in the table of contents] and it illustrates only four species, while the dust-jacket shows another two. The chapter heads and text are enlivened, however, by a delightful series of sketches of nuthatches in action, although even they fail to picture all 24 species. The index also falls short in its coverage, as it seems to reference major topics only, and omits entries even for unusual behaviours that do not meet this criterion; for example, reciprocal preening is noted for Brown-headed Nuthatch, but is absent from the index.

My negative feelings were largely dispelled on reading the book. It is well-written, full of interesting insights, thorough without being heavy, and concise without being dull. Except where important to the thread of his discussion the author does not go into details that are well covered elsewhere, preferring to refer the reader to the other source of more information. This explains the reasons for some of my initial discontent — the illustrations and material on range and identification are well covered in Harrap and Quinn's 1996 account of *Tits, Nuthatches and Treecreepers* [Helm 1996]. The present volume is a monograph on nuthatch hatural history. Indeed, the author sets out to summarize all the information available on the natural history of nuthatches, and I suspect he has succeeded very well.

What of the rather terse coverage of the "other" 23 species? The author reveals that in fact little detailed knowledge exists for most of them. Even for the familiar North American foursome, he says "Despite the large number of descriptive notes on various aspects of their natural history, detailed ecological or behavioural studies are few" and only one involved marked individuals followed over several years. Our birds get 30 pages, and this does indeed seem to provide a comprehensive summary of what is known about them. This lack of information is compensated for to some extent by the relative homogeneity of the entire group. The studies of the Eurasian species reveal parallels with the behaviour of the rest, especially the White-breasted, although certainly intriguing questions also arise.

One of the strengths of a book of this kind is that it does indeed raise intriguing questions, and highlights the absence of knowledge in areas where studies are lacking. This monograph proves a thorough and lucid account of nuthatch natural history. Given the author's clear affection for his subjects, it should also stimulate interest in this delightful and thoroughly entertaining group of birds.

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Animal Tracks of Ontario

By Ian Sheldon. 1997. Lone Pine. Edmonton. 160 pp. illus. $7.95.

The problem with most "field guides" is that they are too large to carry into the field. This handy little volume (less than 15 × 11 cm) could actually fit into a large pocket. It concisely covers the large and medium-sized mammals, representative species of smaller mammals such as voles and shrews, as well as a few birds, amphibians and reptiles. Each species is allotted a two-page spread. One page provides a detailed illustration of the fore and hind tracks, the normal gait pattern, as well as measurements of the tracks, stride, straddle, and the animal itself. This information is in inches and centimetres. Inexplicably, the author places the imperial measurements first. The facing page has a black-and-white drawing of the species and some life history information, including its approximate distribution in Ontario, and comments on the tracks.

Overall, this is a handy introductory guide, although it does not replace more comprehensive field guides. The book is applicable to eastern Canada in general as most of the species covered are wide ranging. Unfortunately it also has a few problems. The map of Ontario does not even fill an entire page. In true Canadian fashion it labels more cities in the USA than in Ontario and does not even attempt to label the basic ecoregions. The section on non-mammals is commendable, although often vague. For example, frogs, turtles, and snakes each get only one two-page spread. It also contains a few errors, such as suggesting the Wood Turtle (*Clemmys insculpta*) is found in the Windsor area. Nonetheless it is recommended for young naturalists eager to learn the basics of animal tracking.

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A Birder's Guide to the Bahama Islands (including Turks and Caicos)

By Anthony W. White. 1998. American Birding Association. Colorado Springs, Colorado. 320 pp., illus. U.S.$26.95.

There has been a need for an accurate site guide for birdwatchers visiting the Bahamas, and the ABA has now published one. It is one of the excellent "Lane" guides, and those who have used one will know of their high standards. In the Lane tradition, it includes an index, bibliography, glossary, checklist of birds, an annotated bird list, and color photographs of specialties. There is a map for every island, with sites highlighted, and vital information on transportation, or lack of it, to the sites: by bicycle, taxi, or Shank's Pony [on foot], as well as small plane travel between the islands. The length of time taken to walk, ride, or drive to a site is also included. For the bigger islands there are even larger scale maps (1/2″ = 700 feet) showing the trails to a birdwatching site. The precision of the information is impressive and even includes the best and most accessible sites for cruise-ship tourists. One of the checklists is called Finding Bahama Specialty Birds and lists them on a chart of 13 islands with a percentage chance of seeing the birds on a given island. Unquestionably Abaco Island has the largest number of specialties, with a better than 60% chance of seeing 25 of the 33 birds listed. All of the specialty birds are shown in good photographs, and details of their habitat and nesting sites are described in a separate section. The checklist of all the birds that might be seen (313), their status, frequency, and the season makes a quick assessment of the different islands easy. Observable wildlife is also included, as are the local garbage dumps.

As with all guides, the virtues and flaws show up only when they are used *in situ*, but it has the hallmarks of being a first-class tool for birdwatching in the Bahamas.

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American Pronghorn: Social Adaptations and the Ghosts of Predators Past

By John A. Byers. 1997. University of Chicago Press, Chicago. xviii + 310 pp., illus. Cloth U.S.$70; paper U.S.$23.95.

American Pronghorn, a species which has seen a dramatic decline in numbers in Saskatchewan and Alberta in the last few years, is the topic of Dr. Byers, book. The information provided is the result of 14 years of research the author undertook in the National Bison Range, Montana. Central themes found in the book are: (1) "that predation has a pervasive, far-reaching effect on the evolution of social adaptation in ungulates such as pronghorn", and (2) "the behaviour of pronghorn, like the anatomy and running ability, often reflects past rather than current adaptation." The author has attempted to argue that this ungulate's present combination of physical and behavioural characteristics is due to past and current adaptations.

The argument is developed in a series of 11 chapters. The author starts with a description of the species, methods, and materials, and goes onto describe behavioural development of the individual as well as the herd. The text is written in a technical manner with each chapter beginning with a general introduction followed by specifics and ending with a summary. The book has been organized to provide easy access to the contents with a detailed table of contents, author and subject indexes. The reader is also provided with an extensive reference listing.

The reader has been provided with a series of tested hypotheses from which an understanding of the American Pronghorn behavioural development has been gleaned. A single herd within a wildlife reserve was studied, not a free ranging herd with human interactions, a more common situation found on the Canadian prairies. Despite this possible shortcoming, Dr. Byers has provided a comprehensive and unique insight into the behavioural adaptations of the American Pronghorn. This is a book which will be in demand from individuals with an interest in grassland wildlife.

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A Guide to the Birds of the West Indies

By Herbert Raffaele, James Wiley, Orlando Garrido, Allan Keith, and Janis Raffaele. 1998. Princeton University Press, Princeton, New Jersey. 511 pp., illus. U.S. $45.

For decades there has been one name in Caribbean birding, Bond, James Bond. The handy guide by 007's namesake provided many with an introduction to the region's birds. Nonetheless, by the 1990s it was out of date, and the time was clearly ripe for a new generation field guide. *A Guide to the Birds of the West Indies*, the result of the collaboration of five authors and two principle illustrators, is a milestone for the region, a boon to both visiting and resident birders. It will also provide a critically important conservation tool, contributing to increased awareness and efforts to conserve the fragile environment of the Caribbean archipelago.

The book follows a well-traveled format. The introductory sections set out the objectives of the book, provide a biogeography explaining the region's peculiarities, and discuss the critical conservation issues facing the region. This is followed by color plates and detailed species accounts. A particularly useful feature is a checklist providing the status of each species in 25 islands or island groupings. The most recent taxonomic developments are reflected, thus for the first time it is possible to see in one convenient place illustrations of the various Stripe-headed Tanagers, several “new” Pewees, and both Gray and Brown Trembler.

The most important features of any field guide are its illustrations, and this book, with 86 color plates, is amply endowed. In setting the plates the authors opted to illustrate every bird which has occurred more than twice, and to include many of the distinctive forms which occur on the various islands. In keeping with the best guides, plates are provided comparing various groups (ducks, hawks, shorebirds, etc.) in flight, and there are separate plates for breeding and non-breeding plumaged warblers. A novel feature are several extra plates displaying the endemic species found in several islands, or providing full-page paintings of particularly charismatic endemic species. The plates emphasize the plumages most likely to be seen in the Caribbean, e.g., basic plumage terns as opposed to breeding plumages. Also, and in keeping with other recent field guides, the plates include concise text pointing out key features.

The quality of the plates is variable, reflecting in part the different styles of the illustrators. Some are excellent, the amazon parrots, nightjars, and cuckoos are as good as in the best guides, and most of the others are up to current standards. However, some are disappointing. The flycatcher plates are crowded and much too dark; conversely, the vireo and winter warblers are rather washed out, rendering them even more confusing than in life. As well, there are a few outright mistakes, for example, the adult male Bahama Yellowthroat is shown with an olive-green cap, not gray. There are also sins of omission. Given that Hispanola constitutes the entire known wintering range of Bicknell's Thrush an illustration of this recent split should have been included, instead it is lumped with Gray-cheeked Thrush. Likewise, the two nighthawks, Common and Antillean, are annoyingly combined in one drawing, despite the note in the text that they can be differentiated on the basis of underwing color. It would have been very helpful to see this illustrated.

The added value of the extra plates is questionable; while most of the full page paintings are excellent (check out the Puerto Rican Nightjar) the plates grouping island endemics together are not as good and add little information. For conservation education purposes, stand alone posters with art clipped from the guide might have been a better call. Similarly, the decision to include extinct species in the main plates will probably confuse more than educate; an alternative approach might have been to consolidate paintings of the extinct species into one or two poignant plates at the end. The decision to illustrate mega-vagrants such as the Orinoco Goose is also questionable; given the omissions noted above the space they take up could have been used to illustrate additional forms or plumages, or to show different views (e.g., there is no flight picture of Red-footed Booby).

The species accounts focus on identification features, similar species, voice, status, and habitat. All major plumages are described, including obvious subspecific variations, and details are provided on flight and other features as appropriate. For many species, there is a short “comments” section which provides useful additional identification information and enhances the readability of the book. Each account includes a map showing the range of the species in the Caribbean. Resident and seasonal ranges are differentiated by solid and dotted lines, and isolated populations on smaller islands are highlighted by arrows. For several Greater Antillean endemics close-up maps show the range on individual islands.

The information provided by the combination of the plates and text should be sufficient to identify most species. The text is generally accurate; however, there are mistakes, for example, the voice described for Willow Flycatcher actually belongs to Alder. For the more difficult groups the reader is referred to the specialist literature, including recent articles in leading ornithological and birding journals. While this is generally a sensible approach, the fact that several difficult Caribbean groups such as the Myirarchus flycatchers were not covered more comprehensively is a disappointment, particularly to those living in areas likely to benefit from the occasional Caribbean stray.

Unfortunately, and totally out of character with other major guides recently released by Princeton University Press, the book has many minor but irritating flaws. These include spelling mistakes, incorrect typesetting, confusing sentences, range maps which contradict the text, and in one bizarre case, the superimposition of the number "4" on the illustration of Swainson's Warbler. These mistakes are inexcusable in a work of this nature and presumably reflect undue haste in getting the book to market. Hopefully they will be addressed in a future edition. These shortcomings should not detract from the overall value of the book. It is an attractive addition to any bird book collection and is destined to become an indispensable tool for any birder or conservationist interested in the Caribbean.

References:

Bond, James. 1960. Birds of the West Indies. Collins, London.

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The Evolution Revolution

By Ken McNamara and John Long. 1998. John Wiley and Sons, Toronto. xii + 298 pp., illus.

Don't be entirely taken in with this title. Yes, *The Evolution Revolution* covers many current themes and research directives such as the evolution of life, to the evolution of horses, but for the most part the book's perspective is hidden in the guise of Australian fossil resources. Unlike other books that are more blatantly titled "fossils from some such country or continent" Ken McNamara and John Long, both from the Western Australian Museum, incorporate not only new discoveries from their home country but relate the broader perspective of such finds, in the context of, for example, the earliest vertebrates, or which creature walked on land first. Unlike other books of similar intentions, *The Evolution Revolution* succeeds in highlighting recent discoveries on the home front with that of the rest of the world.

Acknowledging this bias, Australia, and the more southern continent of Antarctica, are extremely rich and a required journey in deciphering many of the contemporary questions we have about how things came to be. Some of the earliest tracks on land, made by eurypterids, are found there. Sidestepping the "cult" status of the Burgess Shale, the authors highlight the importance of the Cambrian explosion by reviewing the recent discoveries in China as well as Australia. A rare discussion in popular books is a chapter on the early evolution of insects and the subsequent move of some towards flight.

Written for the slightly more advanced lay reader, much of the tales of how science works is enlightening, if not lighthearted. The collecting technique of a large Australian marine reptile, a plesiosaur, is quite entertaining and involves the feared threat of an anthrax breakout. However, there is a danger in giving too much stock, as the authors do, to the printed dialogues of scientists as ideas are tossed around. Interesting to the uninitiated, yes, but this may provide too much weight to unsubstantiated ideas. For example, some discussion is given to the idea of the ability of another group of ancient marine reptiles, mosasaurs, in capturing the nautilus-like ammonites. For the longest time the holes found on these disc-shape invertebrate shells have been attributed to the grasping of these sea-going lizards, and the authors recount noted paleontologist Bob Bakker's verbal confirmation of this idea in the discussion period of a recent conference. Bob Bakker is notorious for making comments like this without following through the regular process of dessemination of scientific information (i.e., a peer reviewed publication). Current research on the mosasaur/ammonite relationships (see Kase et al. 1998, Geology, v. 26) or other interpretations of the same public comments (see Peter Ward's 1998 book *Time Machine*, Springer-Verlag, New York), strongly suggest that if mosasaurs did bite ammonites, their shells were too brittle to absorb the punctures but instead would shatter. The "puncture marks" are more attributed to limpet home scars.

Though comparatively, we know more about the diversity of extinct and extant life in the Northern Hemisphere, there is much to be learned and re-interpreted by searching the southern continents, remembering that tectonic plates were much different in the past. Some of the earliest complete sharks have a southern origin like that of the 380 million year old *Antacrtiliamna*. However, in the absence of good resources, the authors cleverly insert that pronouncement, like in the case of early mammals, "The story of the hunt for Mesozoic mammals in Australia is one of the great searches in palaeontological history" (page 203). Important to find? Yes, but one of the "great" searches. . .? Perhaps not.

The Evolution Revolution has another agenda of sorts. The authors emphasize in many chapters the role of juvenile features that are retained by the adults — paedomorphic features; or the possible continued change, past its ancestor — peramorphic features. The essays on insects, birds, horses, and human evolution are rich in this interpretation of one of the factors in how species change, "For most species are a cocktail of paedomorphic and peramorphic features" (page 233).

It would be an extremely daunting task, to say the least, for any individual to comprehend all the contemporary evidence of the themes in this book. Fortunately, with an invertebrate paleontologist (McNamara), and a vertebrate paleontologist (Long), sharing what they have found, with some fun, and easy translation, many streams of thought are tapped into. Supplementing the essays are numerous black-and-white illustrations by Danielle West, reconstructing a number of the beasts and bugs of the past. These are well done, but it would have been very interesting to see color pictures of the Australian famed opalized plesiosaur skeleton. Overall, *The Evolution Revolution* is a good (Australian?) summation of current trends in our understanding of the evolution and diversity of life of this 4.5 billion-year-old planet.

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BOTANY

Seed Anatomy

By Werker, E. 1997. Handbuch der Pflanzenanatomie, Band X, Teil 3, Gebrüder Borntraeger, Berlin. xii + 424 pp., ISBN 3-443-14024-6, hard, $116 U.S.

This volume represents another significant contribution in the *Handbuch der Pflanzenanatomie* series. Werker's review of the angiosperm seed is encyclopedic, touching on aspects such as functional seed anatomy and morphology, embryology, physiology, dormancy, and germination. The volume is well written and concise, with excellent line drawings, spectacular figures, and a comprehensive reference list. I was delighted to see that the concept of anatomical and morphological variation was recognized and discussed throughout the volume. The no-nonsense style in which the volume is written and presented allows the reader to obtain information quickly and efficiently.

Discrepancies were few and trivial; however, the notion that large seeds of arboreal taxa are primitive and small seeds of herbaceous taxa advanced conflicts with current thinking on the origin of the angiosperms. For those readers familiar with seed anatomy and morphology, the terminology is not overwhelming, but a glossary would have been a nice touch. The only problem that I was able to identify was the lack of a standardized terminology. While such problems are common in most botanical disciplines, this book would have been the appropriate venue to deal with some of these etymological inconsistencies.

Although its cost is prohibitive for most undergraduate and graduate students, I highly recommend this volume for anyone working or beginning to work on angiosperm seed anatomy and morphology.

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Guide to the Vascular Plants of Florida

By Richard P. Wunderlin. 1998. University Press of Florida, Gainesville. x + 806 pp. U.S. $35.00.

Richard Wunderlin in 1982 published *Guide to the Vascular Plants of Central Florida* and in 1996 Wunderlin, B. F. Hansen, and E. L. Bridges produced *Atlas of Florida Vascular Plants* (CD-ROM). Other floras of various parts of Florida exist but the Atlas and the Guide are the first to cover the whole of this state.

In this work 224 families, 1306 genera and 3834 species plus pertinent subspecies and varieties are treated. The arrangement is explained in the introduction "four major sections: pteridophytes, gymnosperms, monocotyledons, and dicotyledons". The family arrangement of the pteridophyte section follows Crabbe et al. (1995) with some modifications, the gymnosperm section follows Pilger (1926), and the flowering plants follow the Englerian system (Engler 1964) with some modifications. Within the families, genera, and species are in alphabetical sequence.

The text begins with a key to the Major Vascular Plant Groups followed by keys to the families within each of the four groups. Within each family a key is provided for the genera if more than one and for the species if there are two or more species in a genus. Accepted scientific names are in bold face and pertinent synonyms in italics. Common names are those in general use in Florida and follow the scientific name in CAPITAL LETTERS. This is followed by habitats, a note if rare, information on where found in Florida, and reproductive seasons. Endemic taxa are preceded by a bullet (•) and exotic (non-native) taxa by an asterisk (*).

The main text is followed by an 8-page Appendix which includes a number of "additions and changes to the flora which were encountered too late for inclusion in the text", a Synopsis of the Flora, Glossary, Index to Common Names, and Index to Scientific Names. A map of Florida depicting the many counties may be found on the inside front cover.

A proposed multivolume *Flora of Florida* is underway which will include descriptions, detailed synonymy, taxonomic discussions, and a list of excluded taxa. In the meantime the *Guide to the Vascular Plants of Florida* will provide most useful and needed information of the vascular flora of the state of Florida and will certainly stimulate botanical interest throughout the region. The author is to be congratulated for bringing it together.

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Dune Country: A Naturalist's Look at the Plant Life of Southwestern Sand Dunes

By Janice E. Bowers. 1998. The University of Arizona Press, Tucson, Arizona. 156 pp., illus. U.S.$15.95.

In the decades after World War II America was on the move again, this time by ATV and dune buggy. Those in the great metropolises of southern California were heading for the desert and, once there, often making for the sand dunes. It took until the late 1970s before the Bureau of Land Management mustered enough will in the face of political opposition to put in place a scheme of restricted areas for regulating recreational vehicles and a further 10 years before due process allowed it to become permanent. Had they not done so the author of this book would have had little to write about and a unique habitat would have been decimated.

Dune Country was first released under another name in the mid-1980s, part of a wave of interest in desert processes stimulated by that near-death experience. The present volume appears not to have been altered from the original so that one or two name revisions and references to recent book releases such as the new version of *The Jepson Manual* are not included, nor would current research findings have been available.

Ms. Bowers emphasises this is not a scientific exposé of sand dune vegetation but rather a popular introduction to understanding the problems and solutions to living in an unstable environment. Once past the opening she does this well, drawing on her experience as a professional botanist and the works of numerous researchers.

Dealing briefly with the formation and physical properties of dunes, she starts dipping into a trove of variations on a theme of survival and adaption, covering the special problems of staying in place in a shifting world (on one hand wind scouring, on the other burial by sand), nutrient deficiency, responses to temperature and intense sunlight, seed dispersal (not too little yet not too much as to pass outside the dune environment), and plant succession under these conditions. Surprisingly, water supply is not the major issue — in a humid climate sand dunes usually form the most xeric habitat available but in deserts they provide the dampest. Each individual topic is introduced through insights to one of a dozen or so major dune systems with which the author is familiar, from Utah to northern Mexico, and Texas into south-eastern California, and in this way the reader gets to appreciate their singularity. No one model fits all. Every area differs from the others in construction and chemistry, in rainfall timing and, naturally, in floristics. Indeed it is the unique character and separation of major dune occurrences that has created such a high degree of endemism, and this in turn which makes the loss of any one to inappropriate usage a matter of regret and scientific impoverishment. To round out these comparisons Ms. Bowers considers how coastal dunes and major sand systems in other parts of the world present yet further differences.

All this is gathered into a compact 100 pages, following which an expanded bibliography section suggests deeper reading, commenting on some of the material and research studies to be found there and even introducing a few new biological concepts. There is a listing of binomials for decyphering the common names used in the main text and the book ends with a short guide to each of the North American areas referred to, describing their composition and content and some of the logistics for arriving at the right place.

Sand dunes in the south-west USA might sound like a distant subject of only peripheral interest to a Canadian reader, but who cannot benefit from widening their fund of knowledge, particularly of a habitat class not common in Canada and never occuring under such rigorous conditions? Certainly this book should be of interest to Canadian and northern U.S. snowbirds visiting the sun belt, helping them gain an understanding of the world about them. It could even give a useful overview to more dedicated botanists making a once-only trip, while for stay-at-home naturalists, though thousands of kilometres removed, it would provide an absorbing entry into what it takes to be successful under extreme conditions.

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ENVIRONMENT

Global Warming: The Complete Briefing

John Houghton. 1997. Cambridge University Press, Cambridge UK. 251 pp., 11 maps, 83 graphs, 15 tables. cloth U.S. $59.95, paper U.S. $22.95.

"The phrase 'global warming' has become familiar to many people as one of the important environmental issues of our day. Many opinions have been expressed concerning it, from the doom-laden to the dismissive. This book aims to state the current scientific position on global warming clearly, so that we can make informed decisions on the facts."

Following this opening paragraph, Sir John Houghton, Chief of the UK Meteorological Office until his retirement in 1991, Chairman of the UK Royal Commission on Environmental Pollution, and Co-chairman of the Scientific Assessment Working Group of the Intergovernmental Panel on Climate Change, ably fulfills his objectives. He does this in a clear and logical fashion, assessing future scenarios from the perspective of the last million years. For digressions and explanations, short essays within boxes form a commendable stratagem.

The beneficial warming effect of the greenhouse gases in the atmosphere was first recognized in 1827 by the renowned French mathematician, Jean-Baptiste Fourier. In 1957 two Californians, Roger Revelle and Hans Suess, published a paper predicting that *additional* concentrations of carbon dioxide (CO_2) in the atmosphere, caused by human activities, might lead to climate change.

However, CO_2 is only one constituent of the greenhouse gases that may cause global warming. Water vapour is the most important, but its levels are not changing from human activity. The greenhouse gases that are influenced by human activity are CO_2 (70% of the effect to date), methane, nitrous oxide, ozone, and CFCs.

Industrial haze, particularly sulphate particles, has an opposite effect, "global cooling," as do particles carried aloft by sand or dust storms and volcanic dust. For example, the eruption of the Tambora volcano in Indonesia in 1815, caused 1816 to be designated the "year without a summer." Similar cooling effects for one or two years followed the eruptions of Krakatoa, between Sumatra and Java, in 1883 and of Pinatubo in the Philippines in 1991.

Deep ice cores drilled in Greenland and Antarctica have measured the oxygen isotope ^{18}O and showed that the last major ice age began about 120 000 years ago and ended nearly 20 000 years ago. At a depth of 2.5 km the core sampled snow that had fallen on the surface 200 000 years ago. Reconstructions demonstrate the close connections between temperatures and CO_2 and methane.

Not only do various factors interact, but a higher atmosphere temperature may result in both positive and negative feedbacks. The water vapour feedback means that warmer temperatures tend to be wetter. The cloud-radiation feedback depends on the height of the clouds: low clouds reflect heat and have a cooling effect, while high clouds have a blanketing effect and tend to warm the system. Oceans, the main source of atmospheric water vapour, have a large heat capacity and warm more slowly than the atmosphere. Ice and snow reflect solar radiation.

Cold and salty water from near Greenland sinks to the bottom of the sea because of its increased density and then circulates slowly south and east, below South Africa and Australia. The periodic warm waters of El Niño cause perturbations in climate that are predictable a year or more in advance. The "ozone hole," totally unpredicted, was discovered over Antarctica only in 1985; it is caused by chlorine atoms, chiefly chlorofluorocarbons (CDFCs), released into the atmosphere.

Is the problem a simple one? No. After weighing a great mass of evidence, Houghton concludes that anthropogenic effects from CO_2 buildup are the probable cause of the increased temperatures experienced worldwide in this century, and especially since 1980. However, he admits that the slope of such effects on a graph is only just emerging from the "noise" of the natural climate variability experienced in past centuries. By the time evidence is conclusive, it may be too late. The Precautionary Principle, "to anticipate, prevent or minimize the causes of climate change and minimize its adverse effects," was consequently adopted by the United Nations Framework Convention on climate change at Rio de Janeiro in June 1992.

What does the future hold? Uncertainties are substantial, but one probable outcome of the "business-as-usual" scenario ("neither balanced, harmonious, nor sustainable"), as warmer ocean water expands and as glaciers melt, is a rise in sea levels throughout the world. If the sea level were to rise one metre, 7 million people in Bangladesh and another 7 million in Egypt would lose their homes and means of subsistence; the residents of the Maldive Islands, low coral reefs, would lose much of their land area and half of their groundwater supply. The complexity of the systems is such that we cannot rule out surprises, but probable effects would include forest dieback, soil erosion, diminished agricultural production, loss of species diversity, further loss of world fish stocks, and deleterious effects on human health. Change would be relatively rapid; most systems could not respond fast enough. Cereal production could rise in the developed world (by about 5%, resulting from the fertilizing effect of increased CO_2) but decrease in the undeveloped world (by about 10%), further accentuating disparity, increasing hunger and starvation. Thus developing countries, who have done almost nothing to cause the problem, are predicted to be hardest hit. There will be greater perturbations, more cataclysmic weather events, more floods and worse droughts, and increased differences between regions. Maximum warming will be greater at high latitudes in late fall and winter.

Catastrophes have already occurred in some areas. Even now, worldwide, desertification is destroying agricultural potential of 60 000 km^2 each year. In 1970 a storm surge in Bangladesh killed about one quarter million people.

What must be done? The citizens of the world must slow deforestation, promote afforestation, stabilize CO_2 emissions, reduce methane concentrations (this one should be relatively easy to achieve), aggressively increase energy-saving and conservation measures, and develop renewable sources of energy, including solar and wind. The Low-Emissions Supply Systems (LESS) projections could ideally, with intelligent decisions and changes in practice, allow economic growth of 3.3% per annum with an average energy intensity reduction of 2.5% per annum! Houghton cites the forward-looking actions of Sweden (in Uppsala waste incineration provides 80% of the city's heating), Norway (with its carbon tax of US $15 per tonne), Denmark (with tough insulation standards for buildings, and wind power use growing at 10% annually), and of little Fair Isle, Scotland (wind generators supply 90% of the electricity). Photovoltaic cells may be the long-term best energy source and hydrogen the best storage medium.

Scientists must provide better information. Politicians must turn the fine words of the Climate Convention into action. Industry must recognize that environmental concerns are less a threat than an opportunity to grow and flourish. Economists must help devise incentives for appropriate action. Problems of world dimension are increasing disparity between rich and poor, profligate consumption of irreplaceable resources and global security. Societies cannot improve their lot when population growth exceeds economic growth. As US Vice-President Al Gore says, we must embrace the preservation of the Earth as our new organizing principle.

Tim Wirth, US Under Secretary of State for Global Development, has wisely noted, "The economy is a wholly-owned subsidiary of the environment." There are no "technical fixes" available to rescue us; those suggested to date are neither balanced nor sustainable.

Biologists and ecologists, particularly, must understand the long-term implications of global warming. I accept the publisher's claim that this book is the most comprehensive guide available. Ignore it at your peril.

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Ecology: A Bridge Between Science and Society

Eugene P. Odum. 1997. Sinauer, Sunderland, Massachusetts. 330 pp., illus. U.S. $24.95.

The rewrite of Eugene P. Odum's 1977 book *Ecology* has been a long time coming and the resultant work is both welcome and profound. My first reaction was disappointment that the book did not contain more depth since it could be a text foundational for students at all levels. The topics included are a survey of the current fund of knowledge, compiled by the acknowledged master himself, with experience, research, and insight which speak to us of depth accumulated over three generations of ecological research. Not reading a lot of ecological research lately, I was first amazed to find that Eugene P. Odum was still publishing anything, and when I began to read, I was fascinated to see what a readable and easy-to-follow text he had created. I immediately recommended the book to students who had heard comments about it in class and were interested in learning more.

The book covers a wide range of topics in ecology systematically arranged in lesson-plan formats bringing together classic and contemporary issues of ecological significance. His examples include such contemporary illustrations as the movie Apollo 13 (1994) and the Biosphere-2 Experiment (1993) set beside historical studies of the Illinois River and the New York Bight. The task of the book, is to let every person be able to understand a little of how the world functions. Many people are willing to do a little to save the planet, or to preserve their own way of life but aside from media presentations, which are necessarily slanted for entertainment, we have few resources which answer simple questions and profound queries.

Most people who look around them with an eye to conserving, reducing, reusing and recycling, are in tune to the earth as a system and have a notion of the housekeeping which is necessary to preserve the earth. The ecology definition which Odum uses, from the Greek *oikos*, the study of the household is his attempt to relate the entire environment in which we live, to ourselves, necessary parts of the same environment. Understanding how the planet works is basic for survival on our planet, and ecology is the vehicle with which we will become familiar with the workings. Many have tried to answer parts of these questions and this book comes closer in my opinion. Odum suggests that non-science students read only selected chapters, but with his teaching style, it is easier to keep reading when started. I read the entire work in a couple of sittings.

One interesting feature of the book is the series of coloured text boxes set into the text every few pages. These are little vignettes of the state of our world especially with regard to pollution, land-use issues, and political decisions. They are related to the text of the chapters but are like little asides or windows into how some parts of the world are working. Aside or not, they are not to be missed and sometimes I found myself leafing through the book, just reading one box after another.

I recommended this book to university students but I would as quickly recommend it to high school students as a resource and quick-reference text. It is that easily read. Again, the detail is not extensive and it is a quick reference only. But it is timely, the research is up-to-date and the references and suggested readings satisfy the depth that the serious student could want. I enjoyed reading this text and found it worthy of its eminent author.

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Companion to A Sand County Almanac

Edited by J. Baird Callicott. 1987. University of Wisconsin Press, Madison, Wisconsin, 308 pp. Cloth U.S. $27.95; paper U.S. $14.95

Readers who value Aldo Leopold's enormously influential book, *A Sand County Almanac*, will appreciate this companion volume with its "interpretive and critical" essays. Although the past 50 years have eloquently shown that Leopold's 1948 masterpiece communicates powerfully on its own, Callicott's anthology helps to expand one's understanding of the context out of which the initial book was written, to see more clearly both the logic of its structure and the economy of its writing, to have greater awareness of the breadth of its influence and to gain a deeper appreciation of the stature of Leopold himself.

Organized in four sections — The Author, The Book, The Upshot, and The Impact — the Callicott anthology, like *A Sand County Almanac*, "moves progressively from the personal to the universal, from the experiential to the intellectual, from the concrete to the abstract." The first section focuses on Leopold's life, milieu, and intellectual heritage. The second part describes the background and evolution of the famous book and analyses its movement, unity, and structure: "a kind of literary ecosystem" as Callicott puts it. In the third section, there is a philosophical discussion of the final part of

Leopold's book with its articulation of his "land ethic". And in the fourth part the extent of the work's influence is evaluated. The Appendix contains the never-before-published, and more autobiographical, original Foreword to *A Sand County Almanac*, which Leopold wrote in 1947.

In the estimation of the renowned novelist, Wallace Stegner, *A Sand County Almanac* is an "almost holy book in conservation circles ... the utterance of an American Isaiah." Literary scholar, John Tallmadge, echoes this comparison of Leopold to Biblical prophets — "he resorts to the only weapons prophets have ever been able to wield: the strength of truth and the transforming power of language" — then uses a vivid analogy of his own when he describes Leopold's sketches as "moments of insight that point toward a core of truth the way iron filings respond to a hidden magnet."

If there's a single statement in Leopold's work that captures this "core of truth" it is: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." This statement is repeatedly quoted by the various writers of the *Companion to A Sand County Almanac* who, for the most part, support this "core of truth" and affirm the importance of Leopold's thesis. The one note of discord is sounded by historian, Roderick Nash, who criticizes Callicott for overstating the groundbreaking nature of Leopold's ideas and who accuses Leopold of nearly plagiarizing the great English biologist Charles Darwin and of ignoring "the anticipation of ideas" by such writers as John Muir and Albert Schweitzer. In rebuttal, Callicott declares that "Nash works in a well-surveyed woodlot, but using the modern power tools of contemporary historians he has cut various softwoods along with good oak and stacked them in the same cord."

I found some of the essays in *Companion to A Sand County Almanac* rather ostentatious in style and in the use of jargon but, on the whole, I am grateful for the extent to which it has enhanced my appreciation of a volume whose insights, descriptive power and ethical valuation of the natural world I have treasured. Field naturalists who strive to preserve what they observe will find this volume a welcome addition to their library.

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Ecology in Agriculture

Edited by L. E. Jackson. 1997. Academic Press, San Diego. 474 pp. U.S. $79.95.

Ecology in Agriculture is a volume in the Physiological Ecology series. "The intent of this book is to illustrate how the fundamental principles of ecology operate in agricultural settings and how they can be applied to solve practical problems in crop production and environmental management." With the intent is the goal to emphasize ecological study of agriculture at (1) ecophysiological responses of crops, (2) community ecology, and (3) ecosystem processes levels.

Jackson has organised 12 papers, authored by mainly American experts with a few European experts, into three sections in an attempt to achieve the stated intent and goal. The sections are (1) plant responses to the environment, (2) biotic interactions and processes, and (3) ecosystem processes. All papers are technical in nature and follow a similar format. The format includes an introduction, discussion, and review portion followed by a summarization. For readers desiring further information all chapters have reference lists. All papers deal only with crops.

If the papers found within this volume are taken to heart a dramatic rethinking of the blanket recommendations and cultivar development would be required. Maximization of yields could possibly take second seat to ecological and sustained benefits. Development of cultivars could become site oriented not yield. This publication provides insight to a potential agricultural rethinking which may result in a more environmentally friendly industry.

The editor has provided a text which will stimulate discussion within the agricultural industry. Individuals who may benefit from reading this book include researchers, teachers, and students. The one drawback I found with book is its title. The book deals only with crops and as result does not cover agriculture as whole as the title suggests to me.

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Landscapes of the Interior: Re-explorations of Nature and the Human Spirit

By Don Gayton. 1996. New Society Publishers, Gabriola Island, British Columbia. 176 pp., illus. $17.95.

Landscapes of the Interior is a deceptive collection of essays. Based on Don Gayton's many experiences in the region west of the Mississippi, one might easily dismiss the book as yet another mid-life search for the meaning of life. After all, using the new age terminology of the 1990s in the first few pages, Gayton speaks of personal re-exploration, of looking at things differently. Reading on, though, the eighteen essays that comprise *Landscapes of the Interior* have nothing to do with finding the so-called inner child and everything to do with coming to a better understanding of ecological systems and our relationship with them.

Gayton is a wonderful storyteller, and he uses this talent to delve into a number of environmental questions and issues. The accidental burning of an old western red cedar during his adolescence, for example, becomes a vehicle for examining the role of fire in maintaining a healthy and diversified landscape. And a visit to a farm where Manitoba tallgrass is being cultivated leads into a general discussion of preservation and ecological restoration. Larger issues, such as ecosystem management, wilderness versus wildness, and sustainability are tackled in the same way in clear, engaging prose.

Gayton also offers a number of insightful comments about the western interior and its history. He notes that the international boundary (the 49th parallel) effectively split natural regions into two and suggests that over the past century, these separate identities have become more real than imagined. He also observes that the landscapes of the West were regarded by incoming settlers as blank canvases upon which they defined themselves, and that they tended to interact with these landscapes through a set of preconceived cultural values that had little basis in the reality of the land itself. On this last point, Gayton criticizes the tendency of western civilization to look to other cultures and their religions to find a new environmental ethic and argues that one of the challenges facing North Americans today is to build a meaningful connection with the land based on their own cultural traditions and values. *Landscapes of the Interior* is intended as a start in that direction.

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MISCELLANEOUS

Nature's Purposes

Edited by C. Allen, M. Bekoff, and G. Lauder. 1998. Massachusetts Institute of Technology Press, Cambridge. 597+vi pp. Cloth U.S.$55; paper U.S.$30.

The topics of form, function, and design have always been central to biology, and naturalistic bases for them figure large in the controversy between Darwinism and its critics. Volumes of readings can be effective means to introduce such topics, as witnessed by numerous such collections in both biology and the philosophy of science. Unfortunately, despite its topical importance and format, the present book does not deliver. The editors (a philosopher and two biologists) have assembled 22 chapters, nine from the present decade and the remainder older, strangely grouped into five sections.

The first group grounds the concept of function etiologically, in a historical perspective drawing on evolutionary and genetic aspects. Francisco Ayala usefully examines the many senses of biological teleology; Larry Wright engages in some highly detailed philosophical analysis on his way to drawing in natural selection; and Robert Brandon clearly gives a rationale for focussing on adaptation. In the second group, taking an historical perspective, Martin Rudwick argues eloquently for a mechanistic and non-evolutionary approach to the analysis of function in fossils; Walter Bock and Gerd von Wahlert provide a powerful systems-approach to functional morphology and its relation to evolutionary biology; and Ernest Nagel's Dewey Lecture is a valuable review of major contributions to naturalism. There are also three philosophical chapters in which many theoretical matters are reiterated and approaches, such as viewing function dispositionally, proposed.

In the third group, on critical developments, along with four, philosophical, and highly overlapping, chapters, the highlight is the non-adaptational approach to functional morphology propounded by Ron Amundson and George Lauder, in a chapter which, for once, sensibly draws on preceding material. In the fourth group, on "synthesis or pluralism" (these two are antagonistic?), Robert Hinde lucidly explores ethological function in a festschrift to Niko Tinbergen, Philip Kitcher supports a cogent call for pluralism with supportive case studies, and there are yet two more repetitive philosophical chapters. In the fifth group, on design, Carl Gans correctly emphasizes the centrality of adaptation in understanding function and diversity, Stephen Jay Gould and Elisabeth Vrba make a strong case for their concept of exaptation, Lauder superbly builds his case for an historical approach with biological examples and analytical principles, while the other two editors give an inconclusive discussion similar to the introduction.

It is not clear exactly for whom this book is intended. Certainly biologists should be prepared to explore the philosophical issues underlying their work but they can properly expect editors preparing such expositions to make them comprehensive, coherent, and free of organizational conflict. In the present book the two sets of chapters from philosophical and biological authors do not fuse well around the central theme, but maintain an uneasy distance throughout. The biological reader will find the former chapters highly redundant, and filled with critique and counter-critique, which to-ing and fro-ing would require a book-length review to respond to adequately in detail. Much of the material is of doubtful importance for practitioners and hence wearying, in contrast to the pertinent and lively styles of biological philosophers such as David Hull and Michael Ruse. Does nature in fact make all the distinctions postulated by hyperanalytical philosophers? The biological chapters, despite some excellent content, are not brought together in a manner to produce any general consensus on how to move ahead. This edited bolus of nearly 600 pages (and single sentences up to seven lines long) is disappointingly indigestible and inconclusive. Would that the editors (or perhaps just Lauder) had written a well-organized and critical overview, one-third the length, in which the salient biological and philosophical aspects were appropriately emphasized.

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Consilience: The Unity of Knowledge

By Edward O. Wilson. 1998. Alfred A. Knopf, New York. 332 pp. $34.95.

The Holy Grail of physics is a grand unification theory to weld relativity with quantum mechanics. Entomologist, ecologist, and sociobiologist Edward O. Wilson has an even more elusive quest: to unite all human learning, through consilience — a term coined in 1840 by the philosopher William Whewell and meaning a jumping together of knowledge by the linking of facts and fact-based theory across disciplines to create a common groundwork of explanation.

Wilson's goal is not merely to link the major sciences, but to merge the "two cultures" of the sciences and humanities. Wilson argues that accomplishing such a formidable task not only ensures a coherent underlying philosophy to human knowledge, but is essential for our survival. Virtually every environmental crisis humanity faces involves information and decision making from four disparate areas: biology, social science, environmental policy, and ethics. How can these problems be solved when economists think in terms of infinite growth and ecologists of finite (and dwindling) resources?

In one sense, all the major branches of learning are already united because they all emanate from humans. This is a not a trivial point as our biology shapes the way we perceive the world around us. For example, humans perceive only a narrow range of wavelengths of light. What may appear to be a pale yellow blossom to humans could have concentric circles to butterflies that see into the ultraviolet wavelengths. The majority of Wilson's book wrestles with how we perceive, think, and feel shapes science, social science, art, and religion.

Readers exposed to Wilson's earlier work in sociobiology will find much that is familiar. Human gene-culture coevolution ensures that the rich human cultural mosaic is in fact tightly clustered along the theoretical spectrum of possibilities. Wilson cleverly illustrates this point by drafting the possible state-of-the-colony speech of a sentient termite. The self-evident and universal truths of such a species would include "the love of darkness and of the deep, saprophytic, basidiomycetic penetralia of the soil; the centrality of colony life...; the evil of personal rights (the colony is ALL!); our deep love for the royal siblings allowed to reproduce; the joy of chemical song; the aesthetic pleasure and deep social satisfaction of eating feces from nestmates' anuses after the shedding of our skins; and the ecstacy of cannibalism and surrender of our own bodies when we are sick or injured (it is more blessed to be eaten than to eat)" (page 148).

The more ambitious leap is into the realm of the arts and religion — from the quantitative to the qualitative. In terms of bioasthetics, neurologists find peak brain response to designs that contain approximately 20% repetitiveness of elements. Such pattern is found in designs like a simple maze, or, more significantly, a cross with asymmetrical arms. Even beauty does not escape analysis. Humans, regardless of sex or culture, rank a female face as more attractive if it possess high cheekbones, a thin jaw, and large eyes relative to the face. Such traits are rare among women, which is odd if the traits are being selected for. Wilson theorizes that in general such traits may indicate health, vigour, and youth, but perhaps are maladaptive taken to extreme. For example, too delicate features may interfere with reproductive potential. Why then the attraction to such features? Perhaps they represent supernormal stimuli, no different than a gull that rejects its own eggs in favour of a model too large even for the bird to climb on to.

It is in such areas that Wilson treads into dangerous territory. First of all, humans, in general, do not like to think of themselves as mammals, with millions of years of evolution shaping their lives. In addition, to many the distinction between the evolution of traits and tendencies and biological determinism is subtle. To Wilson's credit, he tackles all his subjects sensitively and with respect; he does not attack those that have misunderstood or misrepresented his writing in the past. His greatest flaw is occasionally indulging in unbridled cheerleading for science. Overall, though, this is a work of monumental undertaking and prodigious scholarship that is both lucid and elegantly written.

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A Field Guide to the Life and Times of Roger Conant

By Roger Conant. 1997. Selva, Canyonlands Publishing Group, L.C. Prova, Utah, USA. xix + 498 pp., illus.

This is more an atlas and travel log than a field guide to a life. However, Roger Conant is so renown as the author of the first (1958) field guide to amphibians and reptiles (eastern North America), with subsequent revisions (1975, 1991) in the classic "Peterson" Field Guide Series of Houghton Mifflin, that titling his autobiography as a field guide to him must have been irresistible. The cover design even mimics that of the first edition of the guide.

This is a big book, over 500 pages when the introductory material is added in, and with pages that are 8 by 11 inches (or 20 × 27+ cm Canadian). Even this space is little enough to cover a life so long and so varied. Conant traces himself through his childhood early interest in reptiles, though his apprenticeship at the Toledo Zoo in Ohio, his move to the Philadelphia Zoo in Pennsylvania, his long tenure there as Curator of Reptiles and eventually Director with a major influence on world zoo philosophy.

But wait, that is not all. Although not university-trained Roger kept the company of some of the giants of pre-mid century herpetology in North America, and his natural eagerness for quality work and an observant nature made him an apt pupil both of field herpetology and the scientific approaches of his colleagues. He soon produced not only a series of well-received papers but also *The Reptiles of Ohio* (1938, reprinted with an extensive supplement update in 1951), which still stands as one of the best state accounts ever done, with a wealth of detail on variation in the region based on an incredible field work base. His papers on the water snakes in the *Natrix* (now *Nerodia*) *erythrogaster* complex in the eastern United States and coauthorship of the description of a new subspecies in the *sipedon* complex (the [Lake Erie] Island Water Snake, *N. s. insularum* Conant and Clay 1937) led him to expand his interest in the genus into Mexico, many expeditions there, and ultimately to a monograph on the forms in that country and more descriptions of new taxa.

But there is more. His eastern North American field guide set the standard for amphibian and reptile field identification for the rest of the century. Modifying the techniques pioneered by Peterson on birds, grouping related species on one plate with bars to distinguishing characters and a text with a section contrasting the unique features of otherwise similar species, this book brought precise amphibian and reptile identification out of the museums and into the hands of every field worker. The range maps were a level of accuracy not known up until then, as Conant corresponded with virtually all in eastern North America who might have relevant information whether they were established authorities or emerging neophytes, treating them alike if satisfied that they took care in their observations. The illustrations were the centrepiece of pride. His wife, Isabelle Hunt Conant, a photographer of rare patience, learned an exacting hand-colouring technique and posed countless individuals of virtually every species in the eastern half of the continent to produce comparative images of every species and visually distinctive subspecies in the area. Not only did the book have a profound effect on both the professional and growing amateur herpetological community, but Roger's easy but exacting friendship spread widely. His willingness to help and encourage all, and yet suffer no hasty or sloppy effort from anyone, set a tone for herpetology which did almost as much good as the information he presented in capsule form.

But his story did not conclude there. After he retired from the Philadelphia Zoo and finished his Mexican Water Snake monograph he embarked on a project equally as challenging as anything he had previously tackled, a monograph of the mokasin and copperhead genus *Ancistrodon* a group with species in both North America and Asia. This had been started in the 1930s with a colleague, Howard K. Gloyd at the University of Chicago, but the collaboration was abandoned when Conant became immersed in so many other projects. Gloyd had persisted in accumulating data however, and when he retired had planned to complete it. Cancer intervened and Conant rejoined the project and saw it to completion after Gloyd's death as fulfilment of a promise to his colleague. A widower by this time, the collaboration also brought Conant to eventual marriage to Gloyd's widow, and a round of world travels by the two of them, especially to Asia to see some of the local *Ancistrodon* and their habitats before completing the monograph.

The accounts of achievements and standards are a joy to read, but the book is not just a recounting of unremitting pleasures. Letdowns by those depended on, the toll of personal losses of mother, wife and treasured friends' and traumas of illnesses of his own and others, are events inevitable in life of close bonds and many years, and these are recounted frankly. Those who failed him are not treated gently here, though that they are often not identified except by context, but those who helped and supported are expansively acknowledged.

Conant covers his life by topics spread over 62 chapters each focused on a major theme but interwoven. But it does not end there, as historical reflections on "Zoos then and now" and "Herpetology then and now" are added at the end along with some philosophical after-reflections on the state of the world ("Breed and greed", "Some final thoughts" and an "Assemblage of Anecdotes") which had not found their way into the main text. It ends with "The Vignettes" in two sections "Herpetologists I have known" and "Zoo personalities I have known".

Colleagues of Roger Conant will be indebted to him for having filled in so many corners of the life many of us knew only partly; those who know only the field guide or science papers and monographs, should find it fascinating to have their author come so vividly to life in the context of his times and associates.

Thanks Roger. And thanks to the Toledo Zoo, where Roger started from, for sponsoring this publication.

FRANCIS R. COOK

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NEW TITLES

Zoology

*Bat biology and conservation.** 1998. Edited by T. H. Kunz and P. A. Racey. Smithsonian Institute Press, Washington. 576 pp., illus. U.S. $60.

*BC wildlife: selected British Columbia mammals an interactive CD-ROM.** 1998. By C. W. Chestnut, L. Hammond-Kaarremaa, and D. Salisbury. University British Columbia Press (distributed by Raincoast, Vancouver) 460 Mbt. $34.95.

*The bird almanac: the ultimate guide to essential facts and figures of the world's birds.** 1999. By D. Bird. Key Porter, Toronto. 460 pp. $24.95.

*Encyclopedia of reptiles and amphibians.** 1998. Edited by H. G. Cogger and R. G. Zweifel. 2nd edition. Academic Press, San Diego. 240 pp., illus. U.S. $34.95.

Gila monster: facts and folklore of America's Aztec lizard. 1999. University of Utah Press. Salt Lake City. 129. pp., illus. U.S. $10.95.

†**A guide to the birds of India, Pakistan, Nepal, Bangladesh, Bhutan, Sri Lanka, and the Maldives.** 1999. By R. Grimmett, C. Inskipp, and T. Inskipp. Princeton University Press, Princeton. 888 pp., illus. U.S. $85.

*A Kansas snake community.** 1998. By H. Fitch. Kreiger, Melbourne, Florida. xi + 165 pp., illus. U.S. $42.50.

Mammals of China. 1999. By S. Helin and L. Houji. China Forest Publishing House (distributed by Raincoast, Vancouver). 320 pp., illus. $27.95.

†**Modern wildlife painting.** 1999. By N. Hammond. Yale University Press, New Haven. 240 pp., illus. U.S. $50.

Mountain sheep of North America. 1999. Edited by R. Valdez and P. R. Krausman. University of Arizona Press, Tucson. 353 pp., illus. U.S. $55.

Night comes to the Cretaceous: dinosaur extinction and the transformation of modern geology. 1998. By J. L. Powell. Freeman, New York. xvi + 250 pp., illus. U.S. $22.95.

Orcas in our midst. 1998. By Sunburst Communications. CD-ROM. U.S. $99.95.

Sea creatures with many arms. 1998. By D. M. Souza. Carolrhoda, Minneapolis. 40 pp., illus. U.S. $14.95.

†**Starlings and mynas.** 1999. By C. Feare and A. Craig. Princeton University Press, Princeton. 284 pp., illus. U.S. $ 39.50.

†**Transients: mammal-hunting killer whales of British Columbia, Washington, and southeastern Alaska.** 1999. By J. K. B. Ford and G. M. Ellis. University British Columbia Press (distributed by Raincoast Vancouver) 108 pp., illus. $22.95.

†**Tundra plovers: The eurasian, pacific and american golden plovers and gray plover.** 1998. By I. Byrkjedal and D. Thompson. T & A. D. Poyser (Academic Press, San Diego) xxxiii + 422 pp., illus. U. S. $34.95.

Botany

Dictionary of plant genetics and molecular biology. 1998. By G. S. Miglani. Hawthorn Press, New York. ix + 348 pp., illus. U.S. $44.95.

Ecology of Sonoran Desert plants and plant communities. 1999. Edited by R. H. Robichaux. University of Arizona Press, Tucson. 312 pp., illus. U.S. $ 45.

The ferns and fern-allies (Pteridophyta) of Cape Verde Islands, West Africa. 1998. By w. Lobin, E. Fischer, and J. Ormonde. J. Cramer, Stuttgart. iv + 114pp., illus. U. S. $58.

†**Forest ecosystem toposequences in Manitoba.** 1998. By C. A. Zoladeski, R. J. Delorme, G. M. Wickware, I. G. W. Corms, and D. T. Allan. Canadian Forestry Service (distributed by Raincoast, Vancouver) 63pp., illus. $19.95.

Not just trees: the legacy of a Douglas-fir forest. 1999. By J. C. Dirks-Edmunds. Washington State University Press. (distributed by Raincoast, Vancouver), 336 pp., illus. Cloth $52.95; paper $34.95.

***Ontario plant list.** 1988. By S. G. Newmaster. A. Lehela, P. w. c. Uhlig, S. McMurray, and M. J. Oldham. Ontario Forest Research Institute, Sault Ste. Marie.

***Plants of British Columbia: scientific and common names of vascular plants, bryophytes, and lichens.** 1998. By H. Qian and K. Klinka. University British Columbia Press, Vancouver. xiv + 534 pp. $135.

Environment

American nature writing 1999. 1999. Selected by J. A. Murray. Oregon State University Press. (distributed by Raincoast, Vancouver). 256 pp., $23.95.

†**The ecotraveller's wildlife guide to Belize and northern Guatemala.** 1999. By L. Beletsky. Academic Press, San Diego. xii + 488 pp., illus. U.S. $27.98.

A field trip to the rainforest delux. 1998. By Sunburst Communications, Pleasantville, New York. CD-ROM. U.S. $89.95.

Human/nature: biology, culture, and environmental history. 1999. Edited by J. P. Herron and A. G. Kirk. University New Mexico Press. (distributed by Raincoast, Vancouver). 176 pp. $23.95.

Mysteries of nature. 1998. By Cambridge Educational, Charleston, West Virginia, CD-ROM. U. S. $89.

In search of swampland: a wetland sourcebook and field guide. 1998. By R. W. Tiner. Rutgers University Press, New Brunswick, New Jersey. xviii + 264 pp., illus. cloth U.S. $55; paper U.S. $26.

Nature museum: nature reserves in Yunnan. 1999. By Yunnan Society for Ecological Economics. China Forestry Publishing House (distributed by Raincoast, Vancouver) 196 pp., illus. $49.95.]

***Practical approaches to the conservation of biological diversity.** 1999. Edited by R. K. Bayback, H. Campa III, and J. B. Haufler. Island Press, Washington. xiv + 313 pp., illus. U.S. $65.

Thoreau's country: journey through a transformed landscape. 1999. By D. R. Foster. Harvard University Press, Cambridge. 288 pp., illus. U.S. $ 27.95.

†**Untangling ecological complexity: the macroscopic perspective.** 1999. By B. A. Maurer. University Chicago Press, Chicago. 251 pp., illus. Cloth U.S. $50; paper U.S. $18.

Miscellaneous

Frances Crick and James Watson and the building blocks of life. 1998. By E. Edelson. Oxford University Press, New York. 110 pp., illus. U.S. $20.

John Muir: to Yosemite and beyond. 1999. Edited by R. Engberg and D. Wesling. University Utah Press, Salt Lake City. 171 pp., illus. U.S. $12.95.

†**Minutes of meetings, 1943 to 1949 of the McIlwraith Ornithological Club, London, Ontario, Canada.** 1999. By W. W. Judd. Phelps Publishing (W. W. Judd, 50 Hunt Club Drive, London, Ontario N6H 3Y3) 117 pp. $10.

Mystery of mysteries: is evolution a social construction? 1999. By M Ruse. Harvard University Press, Cambridge. 320 pp., illus. U.S. $27.50.

Books for Young Naturalists

A polar bear can swim: what animals can and cannot do. 1998. By H. Ziefert. Viking, New York. 32 pp., illus. Cloth U.S. $13.89; paper U.S. $3.99.

The best book of bugs. 1998. By C. Llewellyn. Kingfisher, New York. 33 pp., illus. U.S. $10.95.

Internet Sites for Young Naturalists

Young naturalists hold the key to our future. The internet is the key to information science. Here are some top World Wide Web sites for young naturalists as listed by Science Books and Films (December, 1998). I only recogize two

Canadian sites. Comments can be sent to the Book-review Editor, Canadian Field-Naturalist (edith@netcom.ca).

Australian A-Z animal archive	http://www.aaa.com.au/a_z/
Birmingham Zoo	http://www.bhm.tis.net/zoo/
Bug club	http://www.ex.ac.uk/bugclub/
Carnegie Museum of Natural History	http://www.clpgh.org/cmnh/discovery/
Chickadee (Canadian)	http://www.owl.on.ca/chick/chick.html
Children's butterfly site	http://www.mesc.nbs.gov/butterfly.html
Children's Museum, Indianapolis	http://www.a1.com/children/home.html
Cub den (bears)	http://www.nature.net.com/bears/cubden.html
Entomology for beginners	http://www.bos.nl:80/homes/bijlmakers/ento/ begin.html
Field Museum of natural History	http://rs6000.bvis.uic.edu:80/museum
Gorillas	http://www.selu.com/~bio/gorilla/
Houston Museum Natural Science	http://www.hmns.mus.tx.us/
Indianapolis zoo	http://www.indyzoo.com/
Missouri Botanical Garden	http://www.mobot.org/
National Zoological park	http://www.si.edu/organiza/museums/zoo/nzphome.htm
Natural History Museum Los Angeles	http://www.lam.mus.ca.us/lacmnh/
Safari touch tank (Simon Fraser Univ)	http://oberon.educ.sfu.ca/splash/3dlib/thumblab.htm
San Francisco zoo	http://www.sfzoo.com/
Santa Barbara Museum Natural History	http://www.sbnature.org/
Science and nature for kids	http://kidscience.miningco.com/
University of Florida insect records	http://gnv.ifas.ufl.edu/~tjw/recbk.htm
Virtual birder	http://magneto.cybersmith.com/vbirder/
Whale times seabed	http://www.whaletimes.org/whalmpg.htm
Wonderful world of bugs	http://www.ex.ac.uk/~gjlramel/welcome.html

*Assigned for review
†Available for review

Advice for Contributors to *The Canadian Field-Naturalist*

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor**, in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Type the manuscript on standard-size paper, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally words should not be abbreviated but use SI symbols for units of measure. Underline only words meant to appear in italics. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate Documents Cited section. Next list the captions for figures (numbered in arabic numerals and typed together on a separate page) and present the tables (each titled, numbered consecutively in arabic numerals, and placed on a separate page). Mark in the margin of the text the places for the figures and tables.

The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and le **Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

Special Charges — Please take note

Authors **must share in the cost of publication** by paying $80 for each page in excess of five journal pages, plus $15 for each illustration (any size up to a full page), and up to $80 per page for tables (depending on size). Reproduction of color photos is extremely expensive; price quotations may be obtained from the Business Manager. Reprint order forms are included when galley proofs are sent to authors. If grant or institutional funds are available, we ask authors to defray a higher proportion of the cost of publishing, $80 per page for all published pages. Government institutions are expected to pay the full cost of publication. Authors must also be charged for their changes in proofs.

Limited journal funds are available to help offset publication charges to authors with minimal financial resources. Requests for financial assistance should be made to the Business Manager when the manuscript is accepted.

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An order form for the purchase of reprints will accompany the galley proofs sent to the authors.

Francis R. Cook, Editor
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News and Comment

Book Reviews

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Articles

Notes

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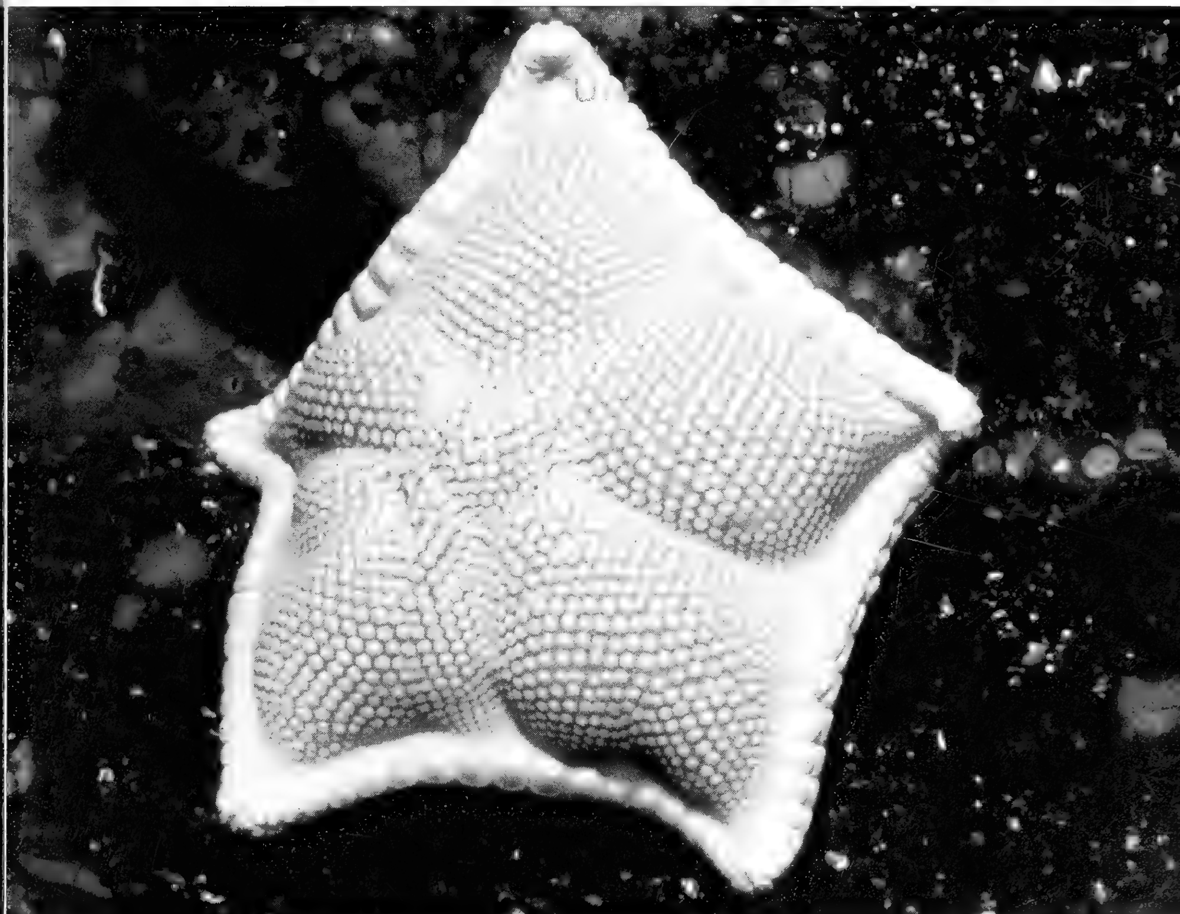

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Distributions of Nine New or Little-known Exotic Land Snails in British Columbia

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Introduced species of terrestrial molluscs of British Columbia were collected between 1989 and 1998. New locality records and expanded distributions are documented for seven introduced land snails: *Lauria cylindracea* (Chrysalis Snail), *Vallonia pulchella* (Lovely Vallonia), *Oxychilus alliarius* (Garlic Glass-snail), *O. cellarius* (Cellar Glass-snail), *O. draparnaudi* (Dark-bodied Glass-snail), *Cepaea nemoralis* (Grovesnail) and *Helix aspersa* (Brown Gardensnail). Two other species, *Vallonia excentrica* (Iroquois Vallonia), and *Vitrea contracta* (Contracted Glass-snail) are reported from British Columbia for the first time. About 25% of the terrestrial mollusc species in the province are exotic. Mechanisms of introduction include transport on nursery plants and on salvaged bricks. Potential impacts on native fauna include predation by *Oxychilus*.

Key Words: *Lauria, Vallonia, Oxychilus, Helix, Cepaea, Vitrea,* introduced land snails, terrestrial molluscs, British Columbia.

Little has been published on either the native or introduced terrestrial molluscs in British Columbia since Pilsbry (1939–1948). Although Rollo and Wellington (1975) provided updated and new information on the European slugs in Greater Vancouver and the lower Fraser Valley, introduced land snails have not received the same attention. Seven species of introduced land snails have been previously reported, in addition to the introduced terrestrial slugs reviewed by Rollo and Wellington (1975). The occurrence of *Oxychilus alliarius* in British Columbia is based on two published records; these were by La Rocque (1953) and Neckheim (1997), who noted this species from Victoria and Greater Vancouver respectively. Neckheim also noted finding two other *Oxychilus*, *O. cellarius*—the first record of the species in British Columbia—as well as *O. draparnaudi*. The latter species was documented earlier by Hatch (1949; see also Hanna 1966) from several greenhouses in the Fraser Valley-Vancouver area. The only British Columbia record of *Vallonia pulchella* is the single locality documented by Cameron (1986) in his study of coastal snail faunas, and Holm (1988, 1994) reported *Lauria cylindracea* from two localities. *Cepaea nemoralis* has been the best documented introduced land snail: Draycot (1961), Spencer (1961), Hanna (1966), Grass (1965) and Neckheim (1997) recorded the snail from various parts of Greater Vancouver. *Helix aspersa* is reported on several occasions in Vancouver and the Fraser Valley (Anonymous 1963a, b; Reid 1980; Schmidt 1981; Mienis 1985). With the exception of *Cepaea nemoralis* and *Helix aspersa*, other introduced land snails are known in British Columbia from only one or two localities, and for all species, many localities were not clearly defined. No attempt had been made to determine species' distributions.

The aim of this study was to identify non-native land snails in British Columbia and determine the distributions of these species in the province. From 1989 to 1998, terrestrial molluscs were collected from over 400 localities; the 80 localities presented here had introduced snails. These species have either gone unnoticed until now or their distribution in the province had never been adequately documented. New localities greatly expand the known distributions of *Lauria cylindracea*, *Vallonia pulchella*, *Oxychilus alliarius*, *O. cellarius*, *O. draparnaudi*, *Cepaea nemoralis*, and *Helix aspersa* in the province, and two new exotic species of land snails, *Vallonia excentrica*, *O. cellarius*, and *Vitrea contracta*, are reported from British Columbia for the first time.

While *Cepaea nemoralis* and *Helix aspersa* are significant as agricultural pests, the other species likely do not have any economic importance. However, *Oxychilus* species are carnivores and potentially reduce diversity of native fauna. The

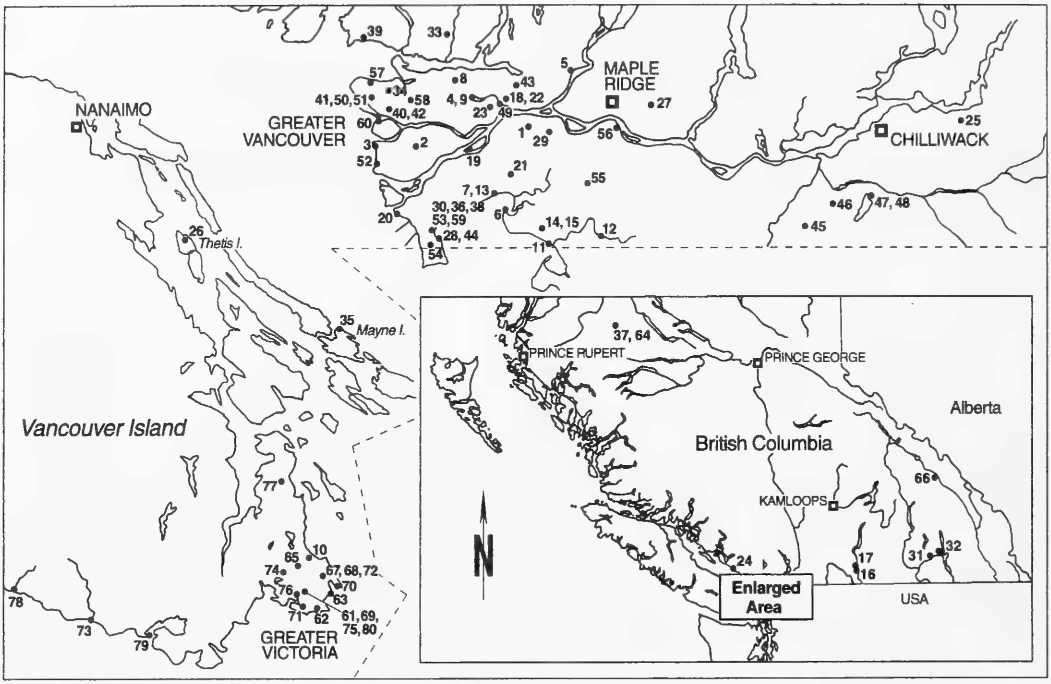

FIGURE 1. Map showing collection localities. Numbers correspond to localities, as listed in the Appendix.

initial introduction and further transport of exotic snails is likely primarily with plants and plant material.

Materials and Methods

Collections were made throughout British Columbia since 1989. The majority of collections yielding introduced land snails were made in Greater Vancouver and east up the lower Fraser River valley, or in Greater Victoria on Vancouver Island. Specimens were collected by hand picking from leaf litter, in grass or other vegetation, or the undersides of (and ground beneath) rocks and wood, and samples were not made for quantitative analysis.

Localities (Figure 1) are documented in the appendix and cited in the text by corresponding number. Some localities were visited more than once. While most material was preserved dry, a limited number of specimens were drowned in water overnight then preserved in 70% ethanol. Voucher specimens consisting of all ethanol-preserved and some dry material are deposited in Royal British Columbia Museum (RBCM), Victoria (Table 1). Additional dry material is in the personal collection of the author. The RBCM was also checked for additional records, which are documented under the appropriate species.

Identifications were made using the publications by Pilsbry (1936–1948), Adam (1960), Kerney and Cameron (1979) and Gerber (1996). The descriptions and figures of Kerney and Cameron (1979) and the key and descriptions of Adam (1960) were most helpful in distinguishing species of glass-snails, genus *Oxychilus*, which are best identified by observing pigmentation and odour of living animals. Live *Oxychilus* were obtained whenever possible. Comparison was made with *Oxychilus* species collected in Britain by J. Hutchinson and H. Reise.

Species List

Lauria cylindracea (da Costa, 1776)

The Chrysalis Snail, *Lauria cylindracea*, is native to coastal regions of western Europe, North Africa, Asia Minor (Kerney and Cameron 1979; Adam 1960), the region surrounding the Black Sea and Caucasia (Likharev and Rammel'meier 1952). It is also known on the Azores, Cape Verde Islands (Backhuys 1975) and Madeira (Cameron and Cook 1996), and is introduced to New Zealand (Willan 1977; Barker 1982). *L. cylindracea* was introduced to Jamaica where it was believed to be a new species and described as *Pupa greyvillei* Chitty, 1853 (Mienis 1994) but the Jamaican population has apparently become extinct (David Robinson, personal communication). In North America, *L. cylindracea* was reported from only two localities, both of them in British Columbia. Holm (1988, 1994) collected *L. cylindracea* at 6531 Riverdale Drive,

TABLE 1. Deposition of voucher material in the Royal British Columbia Museum (RBCM), Victoria.

Species	Vicinity	Locality number*	Museum number
Lauria cylindracea	West Vancouver	39	998-00120-001
	Vancouver	40	998-00122-002
	Vancouver	51	998-00124-001
	Vancouver	58	998-00125-001
	Victoria	76	998-00283-002‡
Vallonia excentrica†	Surrey	6 (6 April 1990)	998-00114-001
	Kootenay Lake	31	998-00118-001
	Smithers	37	998-00119-002
Vallonia pulchella	Surrey	6 (19 October 1995)	998-00117-001
	Kootenay Lake	32	998-00118-002
	Smithers	37	998-00119-001
Oxychilus alliarius	Vancouver	40	998-00122-001
	Coquitlam	43	998-00123-002
	Delta	54	998-00126-001
	Victoria	71	998-00328-001‡
Oxychilus cellarius†	Oak Bay	63	998-00223-001
	Saanich	80	998-00342-002‡
Oxychilus draparnaudi	West Vancouver	39	998-00120-002
	Coquitlam	22 (11 October 1997)	998-00123-001
	Delta	28 (8 October 1997)	998-00121-001
	Oak Bay	62 (14 November 1998)	999-00012-004‡
Vitrea contracta†	Burnaby	4 (11 February 1990)	998-00115-001
	Burnaby	8 (15 June 1990)	998-00116-001
Cepaea nemoralis	White Rock	11	998-00340-001
	Delta	21	998-00339-001
Helix aspersa	White Rock	14	998-00341-001

*A date is given when more than one collection was made at a locality.
†Species newly reported from British Columbia.
‡Preserved in 70% ethanol. All others dry.

Richmond (suburban Vancouver) and in the "Chilliwack Valley in Sardis". The latter record is significant in that it places the species up the Fraser Valley approximately 85 km east of Vancouver.

Lauria cylindracea was collected from 13 localities in this study: on southern Vancouver Island at localities 10, 62, 63, 67, 74, 75, 76 and 77; in Greater Vancouver at localities 39, 40, 51, 57 and 58; and on Mayne Island in the southern Strait of Georgia, at locality 35. The new records demonstrate that this species is much more widespread in the Greater Vancouver region area than previously recognised; they also are the first from the southern Vancouver Island and Mayne Island. *L. cylindracea* was living in mature gardens (localities 40, 58, 74) and road-end areas; the latter are often in close proximity to gardens or are in places where garden waste is often dumped (localities 10, 39, 51, 57, 62, 75). The species has likely been established in the Victoria and Vancouver metropolitan areas for some time and is transported to new locations with plants and garden refuse. At locality 39, *L. cylindracea* occurred along with the much larger *Oxychilus draparnaudi*, and at locality 40, it occurred with *Oxychilus alliarius* and the native *Cochlicopa lubrica* (Müller, 1774) (Glossy Pillar) and *Punctum randolphii* (Dall, 1895) (Conical Spot). On Mayne Island (locality 35), the association of *L. cylindracea* with piles of old bricks (salvaged from demolition sites around Greater Vancouver) suggest another possible means of transport and further demonstrate its ability to be spread by humans.

As in Europe, British Columbia shells are variable in the development of apertural dentition and in form (ovate-conic to elongate-ovate).

Vallonia pulchella (Müller, 1774)

The Lovely Vallonia, *Vallonia pulchella*, is a Holarctic species generally considered native to Europe and northeastern and central North America but introduced in many places worldwide (Pilsbry 1948; Gerber 1996). The only published record for this species in British Columbia is that of Cameron (1986) who collected *V. pulchella* at Popkum, in the Fraser River valley east of Chilliwack, British Columbia.

In this study, *Vallonia pulchella* was found at locality 6 in Greater Vancouver, localities 32 and 66 in the Kootenay region, and locality 37 in Smithers. Additional to these records is a lot in the Royal British Columbia Museum (998-00055-001) from Okanagan Falls, B.C. (E. Thorn, collector; 8 August 1968).

In this study, *Vallonia pulchella* was found to be sympatric with *V. excentrica* at localities 6, 32 and 37. *V. pulchella* is likely widespread throughout

British Columbia in urban and agricultural areas of the province. The most northern station in the province is Smithers (locality 37) and the most eastern station is near Golden (locality 32).

Vallonia excentrica Sterki, 1892

The Iroquois Vallonia, *Vallonia excentrica*, is an abundant Holarctic synanthrope native to Europe and northeastern and central North America. Pilsbry (1948) and Gerber (1996) have summarised its indigenous and non-indigenous distribution worldwide. There are, however, no previous reports of it in British Columbia.

Vallonia excentrica was found at seventeen localities in this study: in Greater Vancouver and the Lower Fraser Valley (localities 2, 4, 5, 6, 12, 29, 43, 45, 46, 52 and 60); on southern Vancouver Island (localities 78 and 79); on the Sechelt Peninsula and on Gulf Islands (localities 24, 26 and 35); in the Okanagan (localities 16, 17); in the Kootenay region (localities 31, 32); and in the Central Interior (localities 37 and 64).

The new locality data show that this species is widespread throughout many urban and agricultural areas in southern British Columbia, and perhaps more so than *V. pulchella*. Locality 37, Smithers, is the northernmost of the records, which suggest that the species will potentially be found elsewhere in the central and eastern British Columbia.

Oxychilus alliarius (Miller, 1822)

Native to Western Europe (Kerney and Cameron 1979), the Garlic Glass-snail, *Oxychilus alliarius* has been introduced worldwide (Likharev and Rammel'meier 1952; Cameron and Cook 1996; La Rocque 1953; Ellis 1969). In British Columbia, *O. alliarius* has been reported from Victoria (La Rocque 1953) and Iona Beach, "Vancouver" (Neckheim 1997), an error for Richmond.

This study found *Oxychilus alliarius* at many localities and often in great abundance. In Greater Vancouver it was at localities 3, 4, 5, 6, 7, 8, 9, 13, 20, 29, 36, 38, 40, 41, 42, 43, 44, 49, 51, 53, 54, 55, 58, 59 and 60; in the Fraser Valley at locality 48; and on southern Vancouver Island at localities 71, 72, 73 and 75.

Oxychilus alliarius is recognised from the next two species by its blackish body. The animal when irritated emits a strong garlicky odour.

Oxychilus cellarius (Müller, 1774)

The Cellar Glass-snail, *Oxychilus cellarius*, is a native of Western Europe (Kerney and Cameron 1979) but is widely introduced to many places worldwide, including the United States and eastern Canada (Pilsbry 1946). *O. cellarius* is known from British Columbia only by the insufficiently documented record by Neckheim (1997) who wrote only that it was found in Vancouver in gardens.

Oxychilus cellarius was collected at localities 10, 63, 68, 69, 70, 74 and 80 in the Greater Victoria area. It was also found in Greater Vancouver at locality 22. Additional to this material, there are two lots in the Royal British Columbia Museum: RBCM 998-00018-002 (Salmon Arm, B.C.; R. Buckell, collector, 1958) and RBCM 998-00013-001 (Victoria, B.C.; E. Thorn, collector, 15 March 1966). These museum records establish that *O. cellarius* has been present in British Columbia for at least several decades. The lot from Salmon Arm also places *O. cellarius* in the southern interior region of the province.

The soft parts of this species are paler than either other introduced *Oxychilus* in British Columbia. The body is pale greyish with darker tentacles and head. The mantle is suffused with brown and there is a row of exceedingly fine brown speckles along each side just above a groove parallelling the edge of the foot. There is no odour of garlic when handled.

Oxychilus draparnaudi (Beck, 1837)

The Dark-bodied Glass-snail, *Oxychilus draparnaudi*, is a native of Western European and the western Mediterranean region (Kerney and Cameron 1979); it is known in the United States (Pilsbry 1946), eastern Canada (La Rocque 1953) and elsewhere as an introduced species. Recently Frest and Rhodes (1982) have summarised its occurrences in the United States. This species was first noticed in British Columbia by Hatch (1949) who reported *Oxychilus lucidum* from greenhouses in Langley Prairie and North Vancouver. Hanna (1966) later implied that Hatch's records were *O. draparnaudi*, and cited Pilsbry (1946) who considered *Helix lucida* Draparnaud, 1801 a synonym of *O. draparnaudi*. Whether Hatch actually had this species is not known, but more recently, Neckheim (1997) noted finding this snail in Vancouver gardens.

Oxychilus draparnaudi was collected at localities 22, 23, 28, 39 and 50 in the Vancouver area, and at localities 61 and 62 in or near Victoria. These new records confirm the occurrence of the species in British Columbia and show that the species is well-established in urban southwestern British Columbia.

At locality 22, a small ravine of largely native flora there coexists both *Oxychilus draparnaudi* and the predacious *Ancotrema sportella* (Gould, 1846) (Beaded Lancetooth), a native snail. Frest and Rhodes (1982) have identified the predacious *O. draparnaudi* as a potential threat to native snail fauna and suggest the possibility that in Iowa it may directly complete with *Haplotrema concavum* (Say, 1822) (Grey-foot Lancetooth), a relative of *A. sportella*. Further investigation is required to confirm the nature of the relationship is between *A. sportella* with *O. draparnaudi* at locality 22. Both snails were living in the humus under Sword Ferns (*Polystichum munitum*) and other plants, but *O. dra-*

parnaudi was more likely also to be crawling in the open. The origin of *Oxychilus* in the ravine can be taken to be the adjacent suburban gardens. There is evidence that dumping of garden waste along the edge of the ravine occurs regularly.

The dark, bluish black animal and larger size of this species best distinguishes it from *O. cellarius*. There is no garlic odour when irritated.

Vitrea contracta (Westerlund, 1874)

The Contracted Glass-snail, *Vitrea contracta*, is a minute snail native to central and northwestern Europe (Kerney and Cameron 1979); Cameron and Cook (1996) also listed it from Madeira. Introduced populations have been located in Palestine (Forcart 1973), the San Francisco Bay area, California (Roth 1977), Lynnwood, Washington (Roth and Pearce 1984), and Toronto, Ontario (Grimm 1996). *V. contracta* has not been identified from British Columbia before.

In this study *Vitrea contracta* has been collected at localities 4, 8, 9, 25, 26, 33, 35, 45, and 47. The new localities are the first records from British Columbia and the northernmost reports of the species on the North American west coast. The Thetis Island (locality 26) and Mayne Island (locality 35) records are of particular interest as they place the species outside of the Greater Vancouver-Fraser Valley regions and indicate that the species may be living on nearby Vancouver Island. At locality 45, *V. contracta* was present with *Punctum randolphii*, *Paralaoma caputspinulae* (Reeve, 1854) (Striate Spot)[1], *Cochlicopa lubrica* and *Vallonia excentrica*, a mixture of introduced and native species, and at locality 35, it was present with *C. lubrica*, *L. cylindracea* and *Monadenia fidelis* (Gray, 1834) (Pacific Sideband).

Cepaea nemoralis (Linnaeus, 1758)

The Grovesnail, *Cepaea nemoralis*, is a medium-sized, often brightly coloured and usually banded snail native to Central and Western Europe (Pilsbry 1939; Ellis 1969; Kerney and Cameron 1979). Pilsbry (1939) recorded it introduced to Ontario and parts of the United States. In the western United States, it is known from California (Pilsbry 1939; Hanna 1966). The first known occurrence of *C. nemoralis* in British Columbia was in 1926 in North Vancouver; this introduction, apparently from eastern Canada in a shipment of ornamental shrubs, was subsequently exterminated according to Draycot (1961). Also documented by Draycot (1961) is a later introduction in 1948, also in North Vancouver, and also supposedly with ornamental plants from eastern Canada. Spencer (1961) found this snail in his Vancouver garden, and Grass (1965) found it in Burnaby. Hansen (1985) examined snails from 65 colonies in the Lower Fraser Valley. Neckheim (1997) reported *C. nemoralis* from Vancouver and Iona Beach, Richmond (part of Greater Vancouver, but not Vancouver, as he indicated).

In the Greater Vancouver region *Cepaea nemoralis* is common and widespread; it was found at localities 1, 6, 11, 15, 18, 19, 21, 23, 27, 29, 30, 33, 34, 42, 54, 55 and 56. It has also been collected in the Fraser Valley (locality 47), on Mayne Island (locality 35) and in Greater Victoria (locality 65).

Additional records for this species are in the Royal British Columbia Museum: RBCM 975-00790-001 and RBCM 975-00790-002 (Edge of road [Highway 19A] by beach, approximately 13 miles [20.8 km] south of Courtenay, Vancouver Island, B.C.; J. Lanko and G. Shane, collectors; 29 April 1960); RBCM 990-00823-001, 990-00824-001, 990-00825-001, 990-00825-002, 990-00825-003 and 990-00825-004 (1137 Balfour Avenue, Vancouver, B.C.; G.W. Gell, collector; various dates: 1985–1990); 998-00070-001 (Rumble Street, south Burnaby, B.C.; Al Grass, collector; August 1966); and 999-00007-001 (Gellatley Road, Westbank, B.C.; Lars Karstad, collector; 22 April 1998).

Helix aspersa Müller, 1774

The Brown Gardensnail, *Helix aspersa* is a large snail native to Western Europe and lands surrounding the western Mediterranean and Black Sea (Pilsbry 1939; Kerney and Cameron 1979). In South Africa, Australia, New Zealand, Central and South America, the United States and Canada, it is introduced (Pilsbry 1939). In Washington, *H. aspersa* has been known there since the 1940s (Burch 1945). Previous reports of *H. aspersa* in British Columbia appear in the agricultural literature; in 1963, three interceptions of this species on ornamental plants from California were recorded (Anonymous 1963a, b). Later, Reid (1980) noted that this snail was found in a residential property in 1979 and a Vancouver nursery in 1980. The following year, Schmidt (1981) reported it in Richmond, Aldergrove, Vancouver, and on the Vancouver-Burnaby border. Mienis (1985) has summarised the accounts published up to that time of the species in Canada.

In this study, *Helix aspersa* was collected at locality 14 in the city of White Rock.

In the collection of the Royal British Columbia Museum, there are two additional records of *Helix aspersa* from 2921 Gosworth Road, Victoria (RBCM 998-00295-001; Tara Steigenberger, collector, 13 October 1998; and RBCM 998-00309-001, Tara Steigenberger, collector, 13 November 1998).

From the paucity of records, it seems likely that *Helix aspersa* is neither a common nor widespread snail in British Columbia, but localised infestations may occur.

[1]*Punctum conspectum* (Bland, 1865) is a synonym of *Paralaoma caputspinulae* according to Roth (1987).

Discussion

The occurrence and method of introduction of exotic molluscs are not well documented in British Columbia. This is especially true of the smaller species which have gone unnoticed or little noticed in the province for some time, and it is not possible to know exactly when or how they arrived here. *Cepaea nemoralis* and *Helix aspersa*, being larger, showier snails have, however, been noticed by naturalists and horticulturists on several occasions and suggest a means of introduction. In British Columbia, Draycot (1961) reported that colonies of *C. nemoralis* were imported from Eastern Canada with shrubs and trees, and similarly, *H. aspera* had been intercepted at Vancouver on ornamental plants originating from California (Anonymous 1963a, b), and for North America in general, Getz and Chichester (1971) noted that most introduced European species of slugs were imported with plant and horticultural material. Of the smaller snails, *Vitrea contracta* has been associated with exotic plant species in San Francisco (Roth 1977), and the Lynwood, Washington population of *V. contracta* was thought to be transported to the site with either leaf litter or nursery stock (Roth and Pierce 1984). The initial introduction and further transportation of exotic snails in leaf litter, garden waste and perhaps soil is probably a common occurrence; Rollo and Wellington (1975) also noted this for the exotic slug, *Arion subfuscus* (Draparnaud, 1805) (Dusky Arion). Populations of *Lauria cylindracea* and *Oxychilus alliarius* suggested a strong tendency to be associated with garden waste. Many of the localities visited were dumps for garden waste, or showed evidence of past dumping. Transportation of small species and eggs on rocks, bricks and wood may also be significant. At the Mayne Island locality, *Lauria cylindracea*, *Vitrea contracta* and the native but highly synanthropic snail *Cochlicopa lubrica* were found on and under bricks which had been salvaged from Vancouver demolition sites. Although these snails could have been transported to the locality on plants and subsequently found refuge among the bricks, it is very possible that the snails were carried to this locality on the salvaged bricks themselves.

The two largest introduced snails, *Helix aspersa* and *Cepaea nemoralis*, are herbivores considered to be significant agricultural pests, but *Vitrea contracta*, *Lauria cylindracea* and perhaps *Vallonia pulchella* and *V. excentrica* likely have little economic impact. Also of little significance to horticulturists, the genus *Oxychilus* has potential to impact upon native snail faunas. *Oxychilus* species are carnivorous but will also eat plant material (Hanna 1966). Frest and Rhodes (1982) suggested that *Oxychilus draparnaudi* may play a role in reducing the local native snail fauna diversity in Iowa. In the present study, native molluscs (except for some particularly synanthropic species) were not regularly encountered in the same location as introduced snails, whether *Oxychilus* species were present or not. Introduced snails were seldom found in completely undisturbed sites, and destruction of suitable habitat could potentially be a greater force acting against native species than predation by *Oxychilus*.

Introduced terrestrial snails form a major component of the terrestrial molluscs in British Columbia and together with the introduced slugs form approximately 25% of the total number of terrestrial mollusc species in British Columbia (unpublished data); terrestrial snails are much more widespread in the province than has been indicated in the literature. New information on *Lauria cylindracea* indicates that the species is a well-established, although locally, in both the Vancouver and Victoria areas. *Vallonia excentrica*, newly recorded from the province, and *Vallonia pulchella* are possibly distributed over the entire southern and central parts of the province in the urban and agricultural areas. Three species of *Oxychilus* were readily found in urban and rural settings; *O. alliarius* seems to be the more widespread and common based on the collections made, and *O. draparnaudi*, although a relatively large snail, has scarcely been noticed before notwithstanding being common in both Victoria and Vancouver. Populations of *Vitrea contracta* appear to be sporadically distributed, but to confirm this, additional investigation is required. Further study throughout the province will continue to be required to better ascertain the distributions terrestrial molluscs within British Columbia.

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Literature Cited

Adam, W. 1960. Faune de Belgique: Mollusques, 1. Mollusques Terrestres et Dulcicoles. Institut Royal des Sciences Naturelles de Belgique. 402 pages, plates a–d.

Anonymous. 1963a. [Interception of *Helix aspersa*]. Page 86 *in* Canadian Insect Pest Review 41. *Edited by* C. G. MacNay.

Anonymous. 1963b. [Interceptions of *Helix aspersa*]. Page 107 in Canadian Insect Pest Review 41. *Edited by* C. G. MacNay.

Backhuys, W. 1975. Zoogeography and taxonomy of the land and freshwater molluscs of the Azores. Backhuys and Meesters, Amsterdam. xii, 350 + 97 pages, 16 plates.

Barker, G. M. 1982. Notes on the introduced terrestrial Pulmonata (Gastropoda: Mollusca) of New Zealand. Journal of Molluscan Studies 48: 174–181.

Burch, J. Q. 1945. [Letter from Trevor Kincaid, with species determinations by Burch]. Minutes of the Conchological Club of Southern California 52: 1.

Cameron, R. A. D. 1986. Environment and diversities of forest snail faunas from coastal British Columbia. Malacologia 27: 341–355.

Cameron, R. A. D., and **L. M. Cook.** 1996. Diversity and durability of the Madeiran and Porto-Santan snail faunas to natural and human-induced environmental change. American Malacological Bulletin 12: 3–12.

Draycot, W. M. 1961. Mollusks introduced into British Columbia. Canadian Field-Naturalist 75: 164.

Ellis, A. E. 1969. British snails. A guide to the non-marine Gastropoda of Great Britain and Ireland, Pleistocene to Recent. Oxford University Press. 298 pages, 14 plates.

Forcart, L. 1973. *Vitrea contracta* (Westerlund, 1873) (Zonitidae, Vitreinae) in Palestine. Argamon, Israel Journal of Malacology 4: 7–8.

Frest, T. J., and **R. S. Rhodes II.** 1982. *Oxychilus draparnaldi* in Iowa. Nautilus 96: 36–39.

Gerber, J. 1996. Revision der Gattung *Vallonia* Risso 1826 (Mollusca: Gastropoda: Valloniidae). Schriften zur Malakozoologie 8: 1–227.

Getz, L. L., and **L. F. Chichester.** 1971. Introduced European slugs. Biologist 53: 118–127.

Grass, A. L. 1965. An introduced population of *Helix nemoralis* Linne [sic]. Pacific Northwest Shell News [Pacific Northwest Shell Club, Seattle, Washington] 4: 5a.

Grimm, F. W. 1996. Terrestrial molluscs. *In*: Assessment of species diversity in the mixedwood plains ecosystems *Edited by* I. M. Smith. EMAN (Environmental Monitoring and Assessment Network). CD ROM.

Hanna, G D. 1966. Introduced mollusks of western North America. Occasional Papers of the California Academy of Sciences 48: 1–108 pages, 4 plates.

Hansen, B. N. 1985. *Cepaea nemoralis* in British Columbia, Canada. [Abstract]. Western Society of Malacologists Annual Report (for 1985) 18: 18.

Hatch, M. H. 1949. Studies of the fauna of Pacific Northwest greenhouses (Isopoda, Coloptera, Dermaptera, Orthoptera, Gastropoda). Journal of the New York Entomological Society 67: 141–165.

Holm, G. 1988. *Lauria cylindracea* (da Coata) [sic] a new introduced species to North America. Dredgings [Pacific Northwest Shell Club, Seattle, Washington] 28: 5, 8.

Holm, G. 1994. A second find of *Lauria cylindracea* (Da Costa). Dredgings [Pacific Northwest Shell Club, Seattle, Washington] 34: 3–5.

Kerney, M. P., and **R. A. D. Cameron.** 1979. A field guide to the land snails of Britain and North-West Europe. Collins, London. 228 pages.

La Rocque, A. 1953. Catalogue of the Recent Mollusca of Canada. National Museum of Canada, Bulletin 129 (Biological Series 44): i-ix, 1–406 pages.

Likharev, I. M. and **E. S. Rammel'meier.** 1952. Terrestrial molluscs of the fauna of the U.S.S.R. Keys to the Fauna of the U.S.S.R., Number 43. Academy of Sciences of the U.S.S.R., Zoological Institute. [Translated by the Israel Program for Scientific Translations, Jerusalem, 1962.] 574 pages.

Mienis, H. K. 1985. The brown garden snail, *Helix aspersa*, in Canada. Shell News from Vancouver [Vancouver and District Shell Club, Vancouver, BC] 6: 2–5.

Mienis, H. K. 1994. *Pupa greyvillei* Chitty, 1853, a synonym of *Lauria cylindracea* (Da Costa, 1778) (Gastropoda: Pulmonata: Pupillidae). Basteria 58: 53–54.

Neckheim, C. M. 1997. A visit to Canada with notes on mollusks from the vicinity of Vancouver and Edmonton. Papustyla 111: 1–8.

Pilsbry, H. A. 1939–1948. Land Mollusca of North America (north of Mexico). 1939: The Academy of Natural Sciences of Philadephia, Monograph 3, 1: i–xvii, 1–573, i–ix. 1940: *ibid.*, 1: 575–994, i–ix. 1946: *ibid.*, 2: i–iv, 1–520, i–ix, frontispiece. 1948: *ibid.*, 2: i–xlvii, 521–1113.

Reid, W. 1980. [Interceptions of *Helix aspersa*]. Page 28 *in* Canadian Agricultural Insect Pest Review 58. *Edited by* J. S. Kelleher.

Rollo, C. D., and **W. G. Wellington.** 1975. Terrestrial slugs in the vicinity of Vancouver, British Columbia. Nautilus 89: 104–115.

Roth, B. 1977. *Vitrea contracta* (Westerlund) (Mollusca: Pulmonata) in the San Francisco Bay area. Veliger 19: 429–430.

Roth, B. 1987. "*Punctum pusillum*" (Gastropoda: Pulmonata)—a correction. Veliger 30: 95–96.

Roth, B., and **T. A. Pearce.** 1984. *Vitrea contracta* (Westerlund) and other introduced land mollusks in Lynnwood, Washington. Veliger 27: 90–92.

Schmidt, A. C. 1981. [Interceptions of *Helix aspersa*]. Page 18 *in* Canadian Agricultural Insect Pest Review 59. *Edited by* J. S. Kelleher and R. M. Boyle.

Spencer, G. T. 1961. A record of slugs in Vancouver gardens. Proceedings of the Entomological Society of British Columbia 58: 47–48.

Willan, R. C. 1977. The chrysalis snail (*Lauria cylindracea*) in New Zealand. Poirieria 9: 27–29.

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Appendix: Localities cited in the text

1. 14689 - 106 Avenue, Surrey, B.C. (49°11.7′N, 122°48.8′W). On garden plants; Robert Forsyth, 28 October 1989. *Ibid.*, 5 May 1989.
2. Westminster Highway at Highway 99, Lulu Island, Richmond, B.C. (49°10.2′N, 123°05.1′W). Under pieces of wood and Styrofoam; open, disturbed grassy site; Robert Forsyth, 27 January 1990.
3. W end of Westminster Highway, Lulu Island, Richmond, B.C. (49°10.3′N, 123°11.9′W). On seaward side of the dike, living under logs and smaller pieces of wood; Robert Forsyth, 27 January 1990.
4. W end of Burnaby Lake, near Still Creek, Burnaby, B.C. (49°15.1′N, 122°57.7′W). Open area, under logs on wood chip covered ground; Robert Forsyth, 11 February 1990. *Ibid.*, 17 March 1990.
5. DeBoville Slough, Coquitlam, B.C. (49°17.1′N, 122°43.7′W). Open grassy area; under log, sheet metal and stones; Robert Forsyth, 3 March 1990.
6. Blackie Spit, Mud Bay, Surrey, B.C. (49°03.5′N, 122°52.7′W). Grassy, disturbed area at back of the spit; underneath logs; Robert Forsyth, 6 April 1990. *Ibid.*, 22 December 1991. *Ibid.*, Tammy and Robert Forsyth, 19 October 1995. *Ibid.*, open grassy dunes with small shrubs; Bob Wright, Tammy and Robert Forsyth, 21 June 1997.
7. Dike, Boundary Bay, just E of S end of 112th Street, Delta, B.C. (*ca.* 49°04.7′N, 122°55.5′W). Under burnt logs on seaward side of the dike; Robert Forsyth, 18 May 1990.
8. Undeveloped park, corner of Halifax Street and Woodway Place, Burnaby, B.C. (49°16.1′N, 122°59.6′W). Under logs wooded lot; young Bigleaf Maples (*Acer macrophyllum*); Robert Forsyth and Daryl E. Foote, 15 June 1990. *Ibid.*, Robert Forsyth, 17 December 1997.
9. S shore of Burnaby Lake, Burnaby Lake Regional Park, Burnaby, B.C. (*ca.* 49°14.5′N, 122°57.0′W). Living under planks in a pile of rubbish, in a grassy area among young Red Alders (*Alnus rubra*); Robert Forsyth, 29 June 1990.
10. Churchill Drive at Shelbourne Street, Mount Douglas Park, Saanich, Vancouver Island, B.C. (48°29.5′N, 123° 20.3′W). Under dead wood on ground in ditch along roadside; Robert Forsyth and Daryl Foote, 15 May 1991. *Ibid.*, underside of a small piece of concrete, next to roadway; Douglas-Fir (*Pseudotsuga menziesii*), Oceanspray (*Holodiscus discolor*); some garden waste and garden plants; Robert Forsyth, 30 April 1998.
11. Along Burlington-Northern Railway tracks adjacent to White Rock Beach, W of the mouth of the Campbell River, Semiahmoo Park, Surrey, B.C (49°00.9′N, 122°46.9′W). Tall grass, shrubs; sandy ground; Robert Forsyth, 9 August 1991.
12. Campbell Valley Regional Park, Langley, B.C. (*ca.* 49°00.5′N, 122°38.5′W). Open, grassy field; around the bases of tufts of grass; Robert Forsyth, 26 June 1993.
13. Grove, E of the S end of 112th Street, Boundary Bay, Delta, B.C. (49°05.2′N, 122°54.0′W). Under logs in grass, on seaward side of the dike, above high-tide line; Robert Forsyth, 1 October 1993.
14. City Hall, White Rock, B.C. (49°01.4′N, 122°47.8′W). Garden planted with pansies; Bill A. Forsyth, collector, May 1994.
15. Ravine, Centennial Park, White Rock, B.C. (49°01.7′N, 122°49.0′W). In leaf litter; Bill A. Forsyth, collector, 9 September 1994.
16. E shore of Vaseux Lake, B.C. (*ca.* 49°18′N, 119°32′W). Under leaves on sandy-humus soil, near lake; Tammy and Robert Forsyth, 26 May 1995.
17. Skaha Lake at Kaleden Pioneer Park, Kaleden, B.C. (49°23.2′N, 119°34.8′W). In beach drift; Tammy and Robert Forsyth, 26 May 1995.
18. 343 Richard Street, Coquitlam, B.C. (49°14.6′N, 122°52.9′W). Garden; Tammy and Robert Forsyth, 10 August 1995. Ibid., 23 March 1996.
19. Deas Island Regional Park, Delta, B.C. (*ca.* 49°07.2′N, 123°03.9′W). Under a log in sandy, open area. Tammy and Robert Forsyth, 21 October 1995.
20. Dike, SE of Brunswick Point, Delta, B.C. (49°03.3′N, 123°07.8′W). Under small pieces of wood, just above the high-tide mark; Tammy and Robert Forsyth, 5 November 1995.
21. Watershed Park, Delta, B.C. (49°06.7′N, 122°54.0′W). Edge of clearing in wooded park; on top of leaf litter under Bigleaf maples; Tammy & Robert Forsyth, 12 March 1996.
22. Ravine at 700 block of Pembroke Street, Coquitlam, B.C. (49°14.6′N, 122°52.8′W). Crawling out in open during cool weather; weedy bank of ravine; Tammy and Robert Forsyth, 12 October 1996. Under leaf litter, English Ivy (*Hedera helix*) and Sword Ferns on sides of the ravine; Western Redcedar (*Thuja plicata*), Bigleaf Maple, garden waste; Larry Williams, Tammy and Robert Forsyth, 11 October 1997.
23. 7753 - 13th Avenue, Burnaby, B.C. (49°13.2′N, 122°55.1′W). Under garden rocks; Larry Williams, August 1996. *Ibid.*, under concrete footing of house post; Larry Williams, 16 May 1997. *Ibid.*, February 1998.
24. Sargeant Bay, Sechelt Peninsula, B.C. (49°28.6′N, 123°51.6′W). Under wood in grassy area with low bushes; Tammy and Robert Forsyth, 10 November 1996.
25. Cheam Lake, near Bridal Creek, SW of Popkum, B.C. (*ca.* 49°11.5′N, 121°45′W). On Black Cottonwood (*Populus balsamifera trichocarpa*) leaves, on tall grass beside path alongside the lake; Tammy and Robert Forsyth, 15 November 1996.
26. Overbury Farm, Thetis Island, Strait of Georgia, B.C. (*ca.* 49°00′N, 123°41′W). Dry bank with Arbutus (*Arbutus menziesii*) and Salal (*Gaultheria shallon*) next to shore; Larry Williams, 9 April 1997.
27. 12881 - 256 Street, Maple Ridge, B.C. (49°14.1′N, 122°30.7′W). Rural garden; Jim Kelly, 14 April 1997.
28. Pumping station at E end of 12th Avenue, Delta, B.C. (49°01.5′N, 123°03.1′W). Under small boards on grass, next to pump-house pool; Tammy Forsyth, 14 April 1997. *Ibid.*, Robert Forsyth, 8 October 1997.

29. 9791 - 161A Street, Surrey, B.C. (49°10.8′N, 122°46.4′W). Garden; W. A. Forsyth, 16 April 1997. *Ibid.*, Garden; Tammy and Robert Forsyth, 3 May 1997. *Ibid.* 13 October 1997. *Ibid.*, 20 May 1998.
30. Vacant lot on 16th Avenue near 56th Street, Delta, B.C. (49°01.9′N, 123°03.9′W). Wooded lot. Tammy and Robert Forsyth, 19 April 1997.
31. McDonalds Landing, West Arm, Kootenay Lake, B.C. (*ca.* 49°34.5′N, 117°13′W). Under pieces of wood, grassy area, above high-water under wharf; Tammy and Robert Forsyth, 21 April 1997.
32. Shore of Kootenay Lake, near boat launch S of Kootenay Bay Ferry, Kootenay Bay, B.C. (49°40.4′N, 116°52.3′W). High on beach; wet stony ground; young trees; under logs and driftwood; Tammy and Robert Forsyth, 21 April 1997.
33. Hastings Creek near Hoskings Road, North Vancouver, B.C. (49°19.7′N, 123°01.8′W). Wooded bank. Larry Williams, Tammy and Robert Forsyth, 1 June 1997.
34. Arbutus Street at 13th Avenue, Vancouver, B.C. (49°15.7′N, 123°09.1′W). On sidewalk next to city garden; Tammy Forsyth, July 1997.
35. 507 Bayview Drive, Georgina Point, Mayne Island, Strait of Georgia, B.C. (48°52.4′N, 123°17.2′W). On fruit trees and plants in garden; Tammy and Robert Forsyth, 17 August 1997. *Ibid.* In piles of old bricks and under pieces of wood in gardens; Robert Forsyth, 22–23 July 1998. *Ibid.* In garden; under sticks; Tammy and Robert Forsyth, 3 November 1998.
36. Dike, N of 16th Avenue, Delta, B.C. (49°02.3′N, 123°03.0′W). Logs, Dunegrass (*Elymus mollis*), on shore side of dike; Robert Forsyth, 28 August 1997.
37. 1565 Main St., Smithers, B.C. (54°46.9′N, 127°09.6′W). Under boards and rocks on gravel and under long grass; Tammy and Robert Forsyth, 13 September 1997. *Ibid.*, 1 October 1998.
38. 1700 - 56th Street, Delta, B.C. (49°02.1′N, 123°03.9′W). Under lumber in construction site; Robert Forsyth, 18 September 1997.
39. Caulfeild Park, West Vancouver, B.C. (49°20.2′N, 123°15.0′W). Douglas-Fir, various wild shrubs, English Ivy; Tammy and Robert Forsyth, 5 October 1997.
40. 2537 West 49th Avenue, Vancouver, B.C. (49°13.7′N, 123°09.7′W). Old city garden; Robert Forsyth, 10 October 1997.
41. Musqueam Park, W of Crown Street at S.W. Marine Drive, Vancouver, B.C. (49°14.0′N, 123°11.6′W). Vine Maple (*Acer circinatum*) leaves; on dead wood on Buttercup (*Ranunculus sp.*) and other weeds at edge of lawn; Robert Forsyth, 10 October 1997.
42. Fraser River Park, W end of West 75th Avenue, Vancouver, B.C. (49°12.7′N, 123°09.3′W). Disturbed, grassy area; on poplar leaves; Robert Forsyth, 10 October 1997.
43. Como Lake Park, Coquitlam, B.C. (49°15.5′N, 122°51.3′W). Broken pieces of cement, rocks and asphalt on weedy grass under to Black Cottonwoods; Larry Williams, Tammy and Robert Forsyth, 11 October 1997.
44. Beach access at E end of 3rd Avenue, Delta, B.C. (49°00.5′N, 123°02.1′W). Sandy ground with Dunegrass; Tammy and Robert Forsyth, 13 October 1997.
45. Old Yale Road, near railway crossing 0.5 km NE of Powerhouse Road at Vye Road, Abbotsford, B.C. (49°01.2′N, 122°07.5′W). Western Redcedars, Paper Birch (*Betula papyrifera*) and large Black Cottonwoods; Tammy and Robert Forsyth, 19 October 1997.
46. End of Robinson Road, Vedder Mountain, Chilliwack, B.C. (49°03.8′N, 122°03.5′W). Grassy roadside; under pieces of Western Redcedar bark. Tammy and Robert Forsyth, 19 October 1997.
47. Municipal park, Cultus Lake, B.C. (49°04.4′N, 121°58.6′W). Douglas-Fir, Bigleaf Maple; Tammy and Robert Forsyth, 19 October 1997.
48. Columbia Valley Road, just S of Sleepy Hollow Road, near Cultus Lake, B.C. (49°04.4′N, 121°57.7′W). Grassy roadside; under a piece of plywood; Tammy and Robert Forsyth, 19 October 1997.
49. Hume Park, New Westminster, B.C. (49°14.2′N, 122°53.4′W). Steep bank with Western Redcedar, Red Alder, Bigleaf Maple, Salmonberry (*Rubus spectabilis*), English Ivy; Tammy and Robert Forsyth, 20 October 1997.
50. Camosun Street at West 33rd Avenue, Pacific Spirit Regional Park, University Endowment Lands, University of British Columbia, Vancouver, B.C. (49°14.8′N, 123°11.8′W). Garden waste; Tammy and Robert Forsyth, 25 October 1997.
51. Camosun Street at West 39th Avenue, Pacific Spirit Regional Park, University Endowment Lands, University of British Columbia, Vancouver, B.C. (49°14.2′N, 123°11.8′W). Garden waste; Tammy and Robert Forsyth, 25 October 1997.
52. W end of Steveston Hwy., Lulu Island, Richmond, B.C. (49°08.0′N, 123°11.6′W). In fallen leaves on grassy ground. Tammy and Robert Forsyth, 27 October 1997.
53. Upland Drive at 52nd St., Delta, B.C. (49°01.8′N, 123°04.7′W). Grassy area with garden waste; Tammy and Robert Forsyth, 2 November 1997.
54. NW corner of Dieffenbaker Park, Delta, British Columbia (49°00.3′N, 123°04.3′W). In a small garden with young Bigleaf Maples, native shrubs and non-native plants; Tammy and Robert Forsyth, 2 November 1997.
55. High Knoll Park, near Colebrook Road, Surrey, B.C. (49°05.6′N, 122°40.8′W). Old pasture, under large Bigleaf Maple; Stinging Nettles (*Urtica dioica*); Tammy and Robert Forsyth, 9 November 1997.
56. Houston Trail-head off Allard Crescent, Derby Reach Park, Langley, B.C. (*ca.* 49°12′N, 122°38′W). Western Redcedar; scattered Bigleaf Maples; Tammy and Robert Forsyth, 9 November 1997.
57. N end of Blanca Street, Vancouver, B.C. (49°16.5′N, 123°12.8′W); along trail down the hill to N.W. Marine Drive. Horse Chestnuts (*Aesculus* sp.), ornamental shrubs and Bigleaf Maples; garden waste; Robert Forsyth, 24 November 1997.

58. Queen Elizabeth Park, Vancouver, B.C. (49°14.6′N, 123°06.5′W). On bank N of the restaurant; gardens with a mixture of indigenous and non-indigenous trees and plants; on sticks, rocks, leaves and roots; Tammy and Robert Forsyth, 24 November 1997.
59. N end of Hunter Rd., E of 56th St., Delta, B.C. (49°01.6′N, 123°04.0′W). Edge of parking lot, behind commercial stores; under cedar hedge. Tammy and Robert Forsyth, 30 November 1997.
60. E side of causeway connecting Iona Island to Sea Island, Richmond, B.C. (*ca.* 49°12.7′N, 123°20.0′W). Under wood; grassy, open site. Tammy and Robert Forsyth, 21 December 1997.
61. 2574 Graham Street, Victoria, Vancouver Island, B.C. (48°26.2′N, 123°21.3′W). Under bricks, plants and in a backyard composting bin; Tammy and Robert Forsyth, 7–9 April 1998.
62. Trail below Denison Road, Walbran Park, E side of Gonzales Hill, Oak Bay, Vancouver Island, B.C. (48°24.7′N, 123°19.2′W). On undersides of stones on dry embankment; some grass; Garry Oak (*Quercus garryana*), Oceanspray and several naturalised ornamental plants, including English Ivy; Robert Forsyth, 29 April 1998. *Ibid.*; in leaf litter, under ivy and logs; Larry Williams and Robert Forsyth, 14 November 1998.
63. Cattle Point, Uplands Park, Oak Bay, Vancouver Island, B.C. (48°26.3′N, 123°17.6′W). Grassy area next to rocky outcropping; under willows (*Salix sp.*) and wild rose (*Rosa sp.*); on sticks and underneath a piece of chip-board; Robert Forsyth, 30 April 1998. *Ibid.*, Heike Reise, John Hutchinson, Tammy Forsyth and Robert Forsyth, 14 July 1998. *Ibid.*, Robert Forsyth, 19 July 1998.
64. 4028 1st Ave., Smithers, B.C. (54°47.0′N, 127°10.4′W). Under a plank in garden; Tammy and Robert Forsyth, 16 May 1998.
65. 700 block of Kildonan Road, Saanich, Vancouver Island, B.C. (48°28.9′N, 123°22.8′W). In garden, under rocks; Tammy Forsyth, May 1998.
66. Dogtooth Forest Service Road, at Columbia River, near Golden, B.C. (51°18.7′N, 116°59.5′W). Grassy flat near river; under pieces of wood on disturbed ground; Tammy and Robert Forsyth, 3 July 1998.
67. Glastonbury Rd., N side of Mt. Tolmie Park, Saanich, B.C. (48°27.6′N, 123°19.4′W). Under dead wood on rocky ground; Garry Oak meadow; Tammy and Robert Forsyth, 14 July 1998.
68. Mt. Tolmie Park, Saanich, Vancouver Island, B.C. (48°27.5′N, 123°19.4′W). Garry Oak meadows; in tall grass and under wood; Heike Reise, John Hutchinson, Tammy and Robert Forsyth, 14 July 1998. *Ibid.*, Robert Forsyth, 17 July 1998.
69. Summit Park, Smith Hill, Victoria, Vancouver Island, B.C. (48°26.7′N, 123°21.1′W). Garry Oak meadows; under log, in tall grass; Robert Forsyth, 16 July 1998.
70. Tudor Avenue beach access, Saanich, Vancouver Island, B.C. (48°27.1′N, 123°16.4′N). Under wood; ivy covered ground; Robert Forsyth, 19 September 1998.
71. Beacon Hill Park, N of Goodacre Lake, Victoria, B.C. (48°25.1′N, 123°21.9′W). Under rocks, in leaf litter, and on sticks; Garry Oak, Oceanspray; Tammy and Robert Forsyth, 22 October 1998.
72. University of Victoria, adjacent to Cedar Hill Cross Road, 400 m NW of Crestview Road, Oak Bay, Vancouver Island, B.C. (48°27.4′N, 123°18.5′W). In tall grass and under logs; Garry Oak meadow; Tammy and Robert Forsyth, 23 October 1998.
73. Mouth of Muir Creek, Vancouver Island, B.C. (48°22.8′N, 123°51.9′W). Under logs; open grassy campsite bordered by Red Alder; Tammy and Robert Forsyth, 24 October 1998.
74. Colquitz River Park, Saanich, Vancouver Island, B.C. (48°27.7′N, 123°23.7′W). In leaf litter; on sticks, bark; young Bigleaf Maples, Garry Oak, Douglas-fir; Robert Forsyth, 11 November 1998.
75. Camrose Park, Camrose Crescent, Saanich, Vancouver Island, B.C. (48°27.3′N, 123°21.1′W) "Wild" park; ivy; under grass, sticks, leaves; on ground. Tammy and Robert Forsyth, 23 October 1998.
76. Cecilia Ravine Park, adjacent to Galloping Goose Trail, 300 blk. of Burnside Road East, Victoria, Vancouver Island, B.C. (48°26.9′N, 123°22.7′W). Undersides of rocks, and on maple leaves and dead vegetation. Flat, unkept, grassy area; maples. Robert Forsyth, 21 October 1998.
77. Quarry Park, East Saanich Road, North Saanich, Vancouver Island, B.C. (48°36.7′N, 123°24.9′W). On fallen maple leaf. Robert Forsyth, 4 October 1998.
78. Alongside Hwy. 14, 500 m SE of Jordan River bridge, Jordan River, Vancouver Island, B.C. (48°25.2′N, 124°02.8′W). Disturbed roadside, next to beach; under rocks and sticks; Dunegrass; young Scotch Broom (*Ulex europeus*); Tammy and Robert Forsyth, 24 October 1998.
79. Whiffen Spit, Sooke, Vancouver Island, B.C. (48°21.6′N, 123°42.9′W). Under sticks; grassy, open site; Tammy and Robert Forsyth, 24 October 1998.
80. Alongside Tolmie Avenue, Peacock Hill Park, Peacock Hill, Saanich, Vancouver Island, B.C. (48°27.2′N, 123°21.2′W). Under dead wood and blackberry cane; Robert Forsyth, 8 November 1998.

An Objective Classification of Ontario Plateau Alvars in the Northern Portion of the Mixedwood Plains Ecozone and a Consideration of Protection Frameworks

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To develop an alvar classification system based on grouping criteria generated by data analysis and to apply the system in an evaluation of existing protection frameworks, species lists for 57 Ontario alvars were used to analyze the relationship between sites based on a UPGMA clustering of Jaccard's coefficients. A principal coordinate analysis was used to complimentarily reduce the dimensionality of the data, and this analysis also provided the coordinate axes used to assess available protection frameworks. The sites were classified into nine groups including three major groups and their subgroups: (1) the Smiths Falls, Napanee, and Carden plains all of which were quite distinct, (2) the Bend Bay and Trent River sites which are predominantly alvar savannas lacking some of the characteristic open alvar communities such as pavements, and (3) the Bruce Peninsula and Manitoulin Island region which may be divided into three major subgroups. The floristic basis for the classification is outlined. In the absence of biological data, a geographic framework proved to be the most useful. Classification of sites based on physiographic and climatic regions also proved useful, but the results suggested that strict adherance to arbitrary divisions not supported by analyzed data could lead to substantial gaps within a system of representative protected sites.

Key Words: alvar, savanna, flora, phytogeography, biogeography, rare species, endemic species, physiography, climate, hardiness, protection, conservation, Great Lakes, Ontario, Canada.

"Alvars are naturally open areas of thin soil over essentially flat limestone or marble rock with a more or less sparse vegetation cover of shrubs and herbs with trees absent or at least not forming a continuous canopy" (Catling and Brownell 1995). The concept has recently been expanded to include successional habitats associated with alvars and is sometimes used more broadly to refer to a landscape including both woodlands and openings. Plateau alvars are "alvars on limestone or marble tablelands located inland from shorelines" (Catling and Brownell 1995). An accurate classification of alvar sites is needed (1) to provide a framework for protection by ensuring that variation between sites is taken into account and that the protection system is adequately representative, and (2) as a basis for research aimed at a better understanding of the development and ecology of alvar flora and fauna.

The only previous analysis of relationships among Ontario alvars that is currently available is based on combined lists of vascular plant species for several sites within each of seven arbitrarily defined regions (Catling and Brownell 1995). This largely subjective analysis indicated three major groups of Ontario alvars. These were: (1) the western Lake Erie alvars with a proportionally high component of southern species, but a relatively small proportion of those occurring to the north; (2) the alvars of the Bruce Peninsula and Manitoulin Island with a relatively high proportion of northern and endemic species; and (3) the alvars of central Ontario and eastern Ontario with a moderate representation of northern species, but with a major proportion of southern species. The analysis by Catling and Brownell (1995) did not include the Trent River alvars.

Although the reliability of this analysis was suggested by phytogeographic affinity of plants, distribution patterns of other organisms, and conspicuous endemism and disjunction in flora and fauna, it was not objectively supported with analysed data and the relationships between individual sites were not examined. Groupings below the major levels were unclear. Furthermore the arbitrary nature of the system raised the question as to whether it really provided a better framework than other systems available such as the site district system employed by the Ontario Ministry of Natural Resources (Hills 1959, 1961; Riley et al. 1997). The objective of the work reported here was to (1) develop an objective, floristics-based classification system using grouping criteria generated by data analysis rather than subjectively determined, and (2) use this objective classification system to evaluate some existing frameworks available for the development of a system of protected sites. The scope of the study is confined to the northern portion of the Mixedwood Plains ecozone (Ecological Stratification Working Group 1995) since there is no question about the distinctness of the western Lake Erie sites (Catling and Brownell 1995).

TABLE 1. Locations of 57 alvars on the Ontario contact line that were used in the classification and framework suitability analyses, with their latitudes and longitudes in standard format.

Asseltine	44° 15' 30", 76° 43' 30"
Barrie Island	45° 55' 00", 82° 42' 00"
Batawa	44° 10' 20", 77° 36' 30"
Bear's Rump Island	45° 18' 30", 81° 34' 30"
Bend Bay West	44° 26' 40", 77° 32' 00"
Bend Bay East	44° 26' 40", 77° 31' 20"
Braeside	45° 29' 00", 76° 27' 30"
Burnt Island Harbour	45° 50' 00", 82° 57' 00"
Burnt Lands (DND)	45° 15' 30", 76° 09' 30"
Burnt Lands (Ramsay)	45° 16' 00", 76° 11' 30"
Cabot Head North	45° 14' 30", 81° 17' 40"
Cabot Head West	45° 14' 40", 81° 18' 20"
Camden East	44° 20' 00", 76° 47' 30"
Camden South	44° 20' 00", 76° 46' 30"
Campbellford	44° 16' 37", 77° 48' 04"
Cape Croker	44° 55' 00", 81° 03' 00"
Cape Hurd Road	45° 13' 00", 81° 41' 30"
Carden Plain 1	44° 38' 35", 79° 00' 50"
Carden Plain 4	44° 40' 45", 79° 05' 00"
Carden Plain 7	44° 40' 45", 79° 04' 00"
Carden Plain 5	44° 40' 40", 79° 04' 15"
Carden Plain 2	44° 39' 30", 79° 01' 05"
Carden Plain 6	44° 41' 00", 79° 03' 00"
Carden Plain 3	44° 40' 40", 79° 01' 45"
Clay Bank	45° 20' 00", 76° 24' 30"
Deseronto	44° 10' 50", 77° 07' 05"
Dominion Point	45° 42' 00", 82° 26' 00"
Dorcas Bay North	45° 11' 00", 81° 36' 00"
Dreamers Rock	46° 00' 00", 81° 47' 00"
Dyer Bay Road	45° 06' 30", 81° 26' 30"
Foxey	45° 52' 00", 82° 33' 00"
Glen Miller	44° 09' 30", 77° 35' 30"
Gretna	44° 10' 45", 76° 59' 30"
Hastings Savanna	44° 17' 50", 77° 58' 10"
Hopkin's Bay	45° 12' 20", 81° 38' 40"
Howes Road	44° 18' 00", 76° 39' 00"
Lewis Lake	46° 00' 00", 81° 51' 00"
Little Cloche Island	45° 59' 00", 81° 44' 00"
Little Eagle Point	45° 09' 30", 81° 35' 00"
Lonsdale	44° 15' 20", 77° 07' 10"
Lonsdale Northwest	44° 15' 30", 77° 08' 00"
Macs Bay	45° 47' 00", 82° 41' 00"
Marathon (Pakenham)	45° 20' 30", 76° 08' 00"
Massasauga Point	44° 08' 25", 77° 18' 50"
McGregor Bay	46° 01' 00", 81° 46' 00"
Misery Bay	45° 43' 00", 82° 46' 00"
Odessa North	44° 16' 00", 76° 43' 00"
Odessa South	44° 15' 30", 76° 42' 30"
Panmure	45° 19' 00", 76° 15' 20"
Picton	43° 59' 40", 77° 07' 10"
Pine Tree Harbour	45° 05' 00", 81° 29' 00"
Point Anne	44° 09' 40", 77° 18' 30"
Rozels Bay	45° 54' 00", 82° 35' 00"
Salmon River North	44° 14' 15", 77° 09' 20"
Sneddon	45° 16' 00", 76° 13' 30"
Solmesville	44° 09' 40", 77° 08' 00"
Yarker	44° 22' 00", 76° 47' 40"

Methods

Species lists were prepared for each of 57 alvar sites near the contact line between Precambrian and Paleozoic rock (northern Lake Huron region to eastern Lake Ontario and north to Ottawa Valley) in southern Ontario (Table 1, Figure 1). A site was defined as a mostly open area at least one kilometer from another site and with a minimum area of 0.5 hectares. The species lists were prepared during early summer and late summer visits to each site with two to five hours spent at each location depending on its size. The identifications were made using standard texts (e.g., Gleason and Cronquist 1991) and the names generally follow Newmaster et al. (1998). The lists were derived from open areas at each site. Woodlands with over 40% tree cover were not included. Only native species were used in the analysis. Since the time at each site was adequate to develop a list to which additions were made at a very slow rate after the first half of the visit, we believe that the lists for each site are sufficiently complete for reliable comparisons. The species at a site may depend to some extent on habitat variation and size of the site, but the development of a classification system based on sites does not necessarily have to account for differences between sites. The differences that are accounted for are those that involve groups arising from the classification system. Specimens collected during the study were deposited in the Agriculture and Agri-Food Canada collection (DAO).

The relationships between sites were explored using UPGMA (unweighted pair group using arithmetic averages) clustering of Jaccard's coefficients based on species presence data. A principal coordinate analysis (PCO) was used to complimentarily reduce the dimensionality of the data by reducing it to several major axes of variation and a minimum spanning tree (MST) was superimposed on it to compensate for distortion. For all phenograms produced, a cophenetic value was computed by determining the correspondance of the similarity/dissimilarity matrix with the cophenetic matrix developed from the UPGMA clustering using the Mantel test (Mantel 1967; Hubert 1987). All analyses were done using NTSYS-PC version 1.70 (Rolfe 1992). Additional information on the statistical procedures and their application in ecological studies is provided in Legendre and Legendre (1983) and Pielou (1984).

To determine which of various grouping variables could provide an optimal framework for a system of protected sites, the various grouping variables were analyzed with respect to their relative accounting for variation in the first five PCO axes. The grouping variables considered were: (1) flora based on nine major groups from a phenogram based on Jaccard's coefficient, (2) the subjective regional grouping used by Catling and Brownell (1995), (3) geography based on nine major groups from a phenogram based

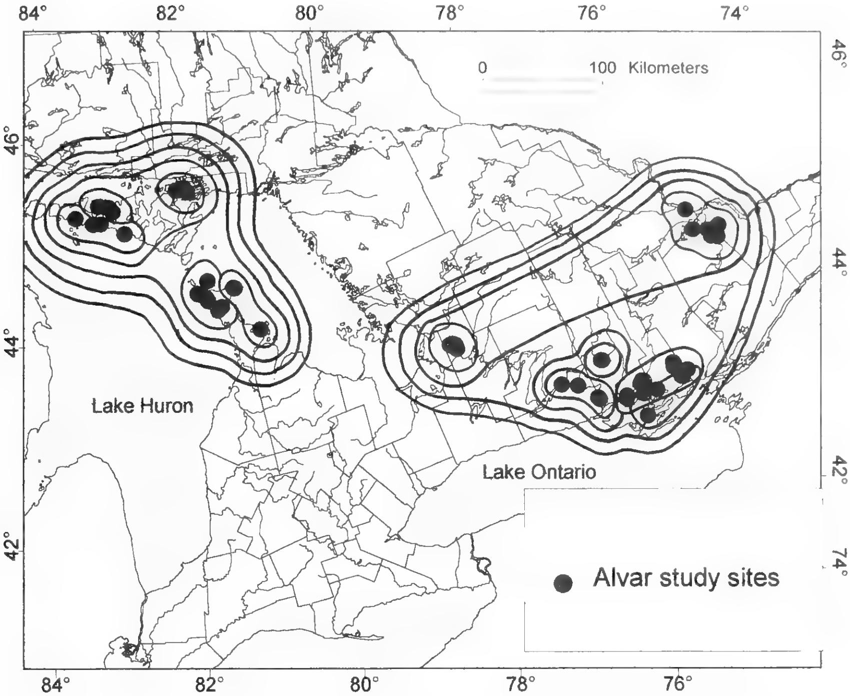

FIGURE 1. Southern Ontario showing locations of 57 Ontario plateau alvars included in the classification study. Contours show relationships between major groups portrayed in UPGMA clustering of sites based on Jaccard's coefficient (Figure 2) and those portrayed in the principal coordinate analysis with minimum spanning tree (Figure 3).

on average taxonomic distance coefficients from latitude and longitude data, (4) physiographic regions from Chapman and Putnam (1984, page 113), (5) climate regions from Brown et al. (1980, page 8), (6) climate based on nine major groups from a UPGMA phenogram derived from a matrix of coefficients of average taxonomic distance based on five climatic variables including growing degree days, July average temperature, January average temperature, summer precipitation and snow cover, (7) site districts employed by the Ontario Ministry of Natural Resources (Riley et al. 1997), (8) ecoregions based on the National Ecological Framework for Canada (Ecological Stratification Working Group 1995), (9) plant hardiness zones from Land Resource Research Centre, Agriculture Canada (1991), and finally (10) site regions employed by the Ontario Ministry of Natural Resources (Riley et al. 1997).

TABLE 2. Grouping variables and their corresponding F-ratios for five principal coordinate axes from analysis of species presence data in 57 alvars using Jaccard's coeffcients.

Grouping Variable	Co-ordinate Axes Values					Sum of F-ratios	No. of Divisions
	1	2	3	4	5		
Flora	189.86	42.29	47.34	28.79	31.73	340.01	9
Catling95	183.01	8.38	17.82	54.24	35.63	299.08	5
Geography	160.12	29.10	32.46	41.98	34.29	297.95	9
Physiographic	109.60	21.95	42.66	23.76	28.97	226.97	10
Climate Regions	151.66	15.62	5.33	35.66	14.29	222.56	6
Climate -5 Types	111.14	9.85	11.36	29.92	28.68	190.95	9
Site Districts	64.91	5.08	19.26	24.88	18.90	133.03	8
Ecoregions	(2.67)	(1.25)	8.48	28.24	21.58	62.22	3
Hardiness Zones	6.42	6.4	18.84	10.52	6.46	48.64	4
Site Regions	11.01	(1.52)	4.45	11.12	16.70	44.80	2

Note: Brackets indicate not significant at the 5% level.

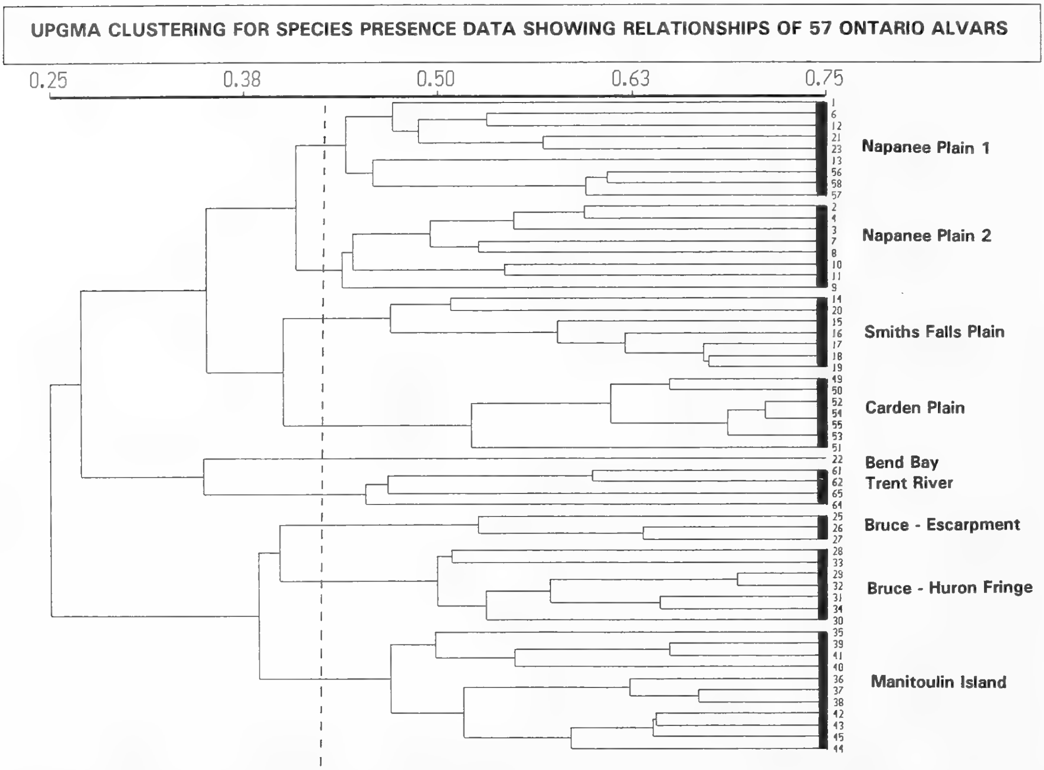

FIGURE 2. UPGMA clustering of 57 alvars from the contact line region of southern Ontario based on Jaccard's coefficients derived from species presence data. The cophenetic correlation was 0.796.

For groupings based on geographic and climatic variables it was necessary first to create phenograms, then select groups by splitting the phenogram at the nine branch level. Since coordinate axes values for the different sites were based on presence of vascular flora, the nine floristic groups classification was expected to have the highest F-ratios. In this sense the vascular flora acts as a standard to assess the effectiveness of other grouping variables.

Results and Discussion

General observations

The phenograms leading to grouping variables were reliable representations of the matrices used to produce them based on cophenetic correlations of 0.796 for flora, 0.921 for geography, and 0.943 for climate based on five characteristics (Table 2). The first five PCO axes explain a small amount of the sample variation: 13.71, 6.20, 5.89, 5.18 and 4.10% (cumulatively 35.09%), which is not unusual for this kind of data. In general major groups were apparent at the nine group level, as seen clearly in the phenogram (Figure 2) based on both floristic data and the PCO with MST (Figure 3) and geographic location (Figure 4).

Classification of sites

The nine group level on the phenogram which is clearly evident in the PCO with MST, includes the five groups subjectively established and clustered previously (Catling and Brownell 1995, Figure 8), thus providing objective support (Figure 1) for this regional approach. The nine groups included three major groups and their subgroups: (1) the Smiths Falls, Napanee, and Carden plains all of which were quite distinct, (2) the Bend Bay and Trent River sites which are predominantly alvar savannas lacking some of the characteristic open alvar communities such as pavements, and (3) the Bruce Peninsula and Manitoulin Island region which may be divided into three major subgroups (Figures 1 and 2). The Napanee Plain was divided into two groups possibly reflecting a difference in openness, human disturbance and adjacent woodland type. The more northern sites on the Napanee Plain generally are richer in native species and associated with diverse conifer-dominated woodland.

The Bruce and Manitoulin sites are distinctive in the presence of many species, including Wild Chives (*Allium schoenoprasum* L. var. *sibiricum* (L.) Hartm.), Cut-leaved Anemone (*Anemone multifida*

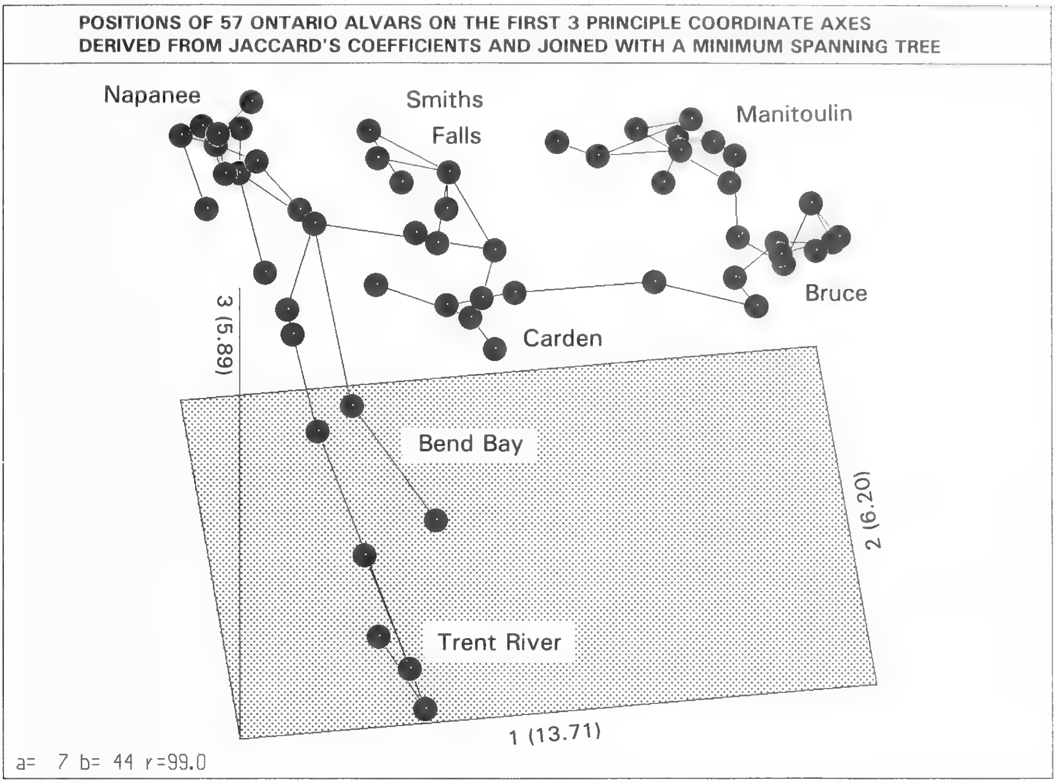

FIGURE 3. Positions of 57 Ontario alvars on the first three coordinate axes based on a matrix of Jaccard's coefficients from species presence data. The sites are joined by a minimum spanning tree which has resulted in a clear regional association of the sites.

Poir.), Wild Calamint (*Calamintha arkansana* (Nutt.) Shin.), Hair-like Sedge (*Carex capillaris* L.), Scirpus-like Sedge (*Carex scirpoidea* Michx.), Lanced-leaved Tickseed (*Coreopsis lanceolata* L.), Hill's Thistle (*Cirsium hillii* (Canby) Fern.), Provancher's Fleabane (*Erigeron philadelphicus* L. ssp. *provancheri* (Vict. & Rousseau) J.K. Morton), Lakeside Daisy (*Hymenoxys herbacea* (Greene) Cusick), Dwarf Lake Iris (*Iris lacustris* Nutt.), Creeping Juniper (*Juniperus horizontalis* Moench), Cylindric Blazing Star (*Liatris cylindracea* Michx.), Purple-stemmed Cliff-brake (*Pellaea atropurpurea* (L.) Link), Alaska Rein Orchis (*Piperia unalascensis* (Spreng.) Rydb.), Alpine Spear Grass (*Poa alpina* L.), Glaucous White Rattlesnake-root (*Prenanthes racemosa* Michx.), Prostrate Sand Cherry (*Prunus pumila* L. var. *depressa* (Pursh) Bean), Cespitose Bulrush (*Scirpus cespitosus* L.), Houghton's Goldenrod (*Solidago houghtonii* Torr. & A. Gray), Ohio Goldenrod (*Solidago ohioensis* Riddell), Rand's Goldenrod (*Solidago simplex* Kunth ssp. *randii* (Porter) Cronquist), and Spike Trisetum (*Trisetum spicatum* (L.) K. Richter). Many of the preceding are northern and/or western or endemic to the Great Lakes basin. In addition the Bruce and Manitoulin sites are distinctive in having species often associated with wetlands on the cool limestone shoreline pavements including Tuberous Indian-plantain (*Cacalia plantaginea* (Raf.) Shin), Twig-rush (*Cladium mariscoides* (Muhlenb.) Torr.), Baltic Rush (*Juncus balticus* Willd.), and Dark-scaled Sedge (*Carex buxbaumii* Wahlenb.). Grass-of-parnassus (*Parnassia glauca* Raf.) and Bird's-eye Primrose (*Primula mistassinica* Michx.) are found in moist seepage cracks along the shores. The Bruce and Manitoulin sites lack species such as Sky-blue Aster (*Aster oolentangiensis* Riddell), White Heath Aster (*A. pilosus* Willd. var. *pilosus*), Low Bindweed (*Calystegia spithamaea* (L.) Pursh), Hay Sedge (*Carex siccata* Dewey), Pennsylvania Sedge (*Carex pensylvanica* Lam.), New Jersey Tea (*Ceanothus americanus* L.), Narrow-leaved New Jersey Tea (*Ceanothus herbaceus* Raf.), and Secund Rush (*Juncus secundus* P. Beauv. ex Poir.). The Bruce sites differ from the Manitoulin sites in lacking *Allium schoenoprasum*, Prairie Smoke (*Geum triflorum* Pursh), *Liatris cylindracea* and Early Buttercup (*Ranunculus fascicularis* Muhlenb. ex Bigelow) and

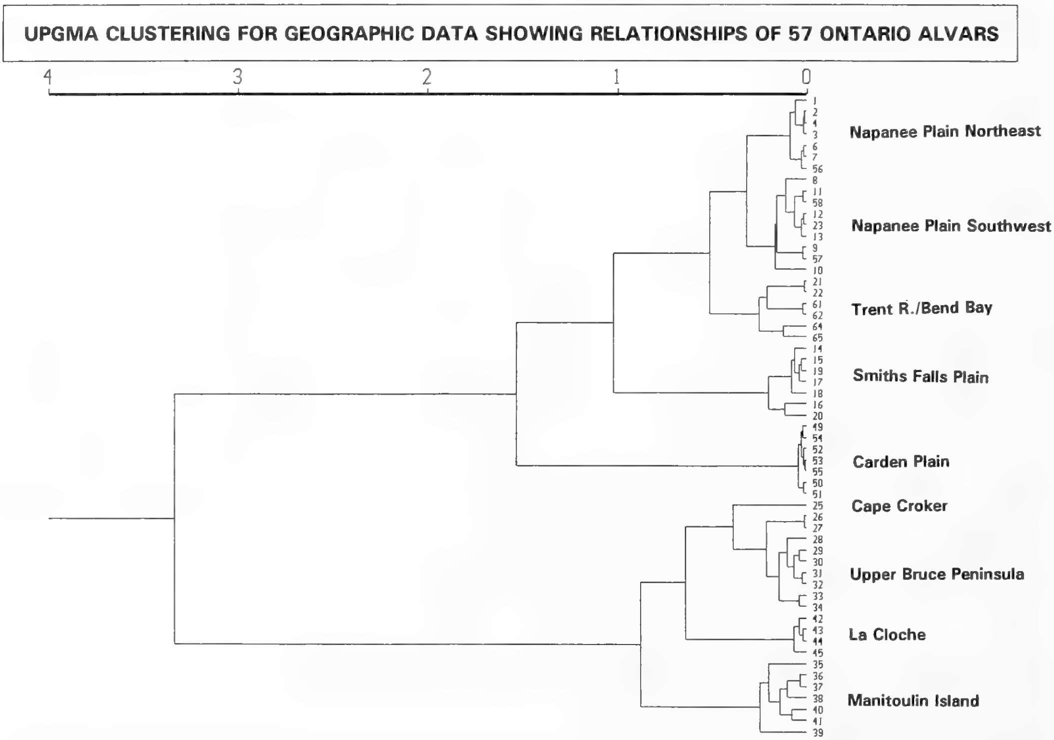

FIGURE 4. UPGMA clustering of 57 alvars from the contact line region of southern Ontario based on Average Taxonomic Distance coefficients from latitude and longitude data. The cophenetic correlation was 0.920.

in having fewer sites with Carolina Crane's-bill (*Geranium carolinianum* L.), Spring Forget-me-not (*Myosotis verna* Nutt.), and Small Skullcap (*Scutellaria parvula* Michx.).

The subsequent branching level in each region separates Lake Huron shore sites from other sites (i.e., those near the North Channel on Manitoulin Island and those inland or near the Georgian Bay shore on the Bruce Peninsula. To the extent that this separation is realistic, it may be explained by the occurrence of boreal and endemic elements, such as *Carex capillaris, Erigeron philadelphicus* ssp. *provancheri, Poa alpina, Primula mistassinica, Solidago spathulata* ssp. *randii*, and Sticky False Asphodel (*Tofieldia glutinosa* (Michx.) Pers.), on the cool, moist, windswept Lake Huron shore sites. Species associated with shallow sand deposits on top of the limestone, such as *Anemone multifida, Cirsium hillii*, and Slender Mountain-rice (*Oryzopsis pungens* (Torr. ex Spreng.) A. Hitchc.), may also contribute to the difference between Lake Huron shore sites and other sites since they are either rare or entirely absent away from the Lake Huron shore. Lyre-leaved Rock Cress (*Arabis lyrata* L.) is frequent on some south shore pavements. On Manitoulin Island, *Hymenoxys herbacea* is confined to the south shore sites. In contrast, Green Milkweed (*Asclepias viridiflora* Raf.), Gattinger's Agalinis (*Agalinis gattingeri* (Small) Small ex Britton & A. Brown), *Myosotis verna*, Switch Grass (*Panicum virgatum* L.) and White Heath Aster (*Aster ericoides* L.) are largely confined to sites on the north shore. Subject to cool onshore winds, Bear's Rump Island clusters with the Bruce Peninsula south shore sites.

As suggested previously (Catling and Brownell 1995), the Ontario sites most closely associated with the Carden Plain alvars are the Smiths Falls Plain alvars, which are also inland and are within a cooler climatic region. They differ from the sites on the Napanee Plain (which are geographically nearer to each) in rarity or absence of species such as *Aster ericoides, Aster pilosus*, Arrow-leaved Aster (*Aster urophyllus* Lindl.), *Carex siccata*, Sartwell's Sedge (*Carex sartwellii* Dewey), American Dragonhead (*Dracocephalum parviflorum* Nutt.), *Myosotis verna*, Yellow Pimpernel (*Taenidia integerrima* (L.) Drude), Venus' Looking-glass (*Triodanis perfoliata* (L.) Nieuwl.), and Narrow-leaved Vervain (*Verbena simplex* Lehm.). The alvars of the Napanee Plain have some unique restricted species (Catling 1995) including Side-oats Grama (*Bouteloua curtipendula* (Michx.) Torr.), Juniper Sedge (*Carex juniperorum*

Catling, Reznicek & Crins), Carolina Whitlow-grass (*Draba reptans* (Lam.) Fern.), Tinted Spurge (*Euphorbia commutata* Engelm.), and Mouse-tail (*Myosurus minimus* L.). Carden Plain alvars support several species that are not found on the Smiths Falls Plain alvars, such as Indian Paintbrush (*Castilleja coccinea* (L.) Spreng.), Common Hairgrass (*Deschampsia cespitosa* (L.) P. Beauv.), Rocky Mountain Fescue (*Festuca saximontana* Rydb.), *Geum triflorum*, *Juncus secundus*, Wild Bergamot (*Monarda fistulosa* L.), Narrow-leaved Panic Grass (*Panicum linearifolium* Nash), Fragrant Sumac (*Rhus aromatica* Aiton), Little Bluestem (*Schizachyrium scoparium* (Michx.) Nees), and White Camass (*Zigadenus elegans* Pursh ssp. *glaucus* (Nutt.) Hulten).

Optimal frameworks

Geographic data provided a good framework for a system of protected alvar sites (Table 2) and a subjective classification based largely on it along with consideration of other factors and common sense is likely to produce a reasonable classification. Consequently, the fact that the geographically-based system employed by Catling and Brownell (1995) had relatively high F-ratios is not surprising. The very useful aspects of the physiographic system employed by Chapman and Putnam (1984) is supported by their having the next highest F-ratios overall. Climatic groupings follow closely as a useful framework for decisions leading to protection of alvar plant species diversity, but there is a substantial gap between geographic grouping and the physiographic-climatic groupings (Table 2). The site district system with eight categories is better than the broader systems with three and two categories, but is still rather poor. Hardiness zones may work for cultivated plants. The situation with cultivated plants, however, is quite different since seeds are protected from cold and the most susceptible younger and germination stages are also protected, and of course regional variation in factors such as competition are not accounted for. Furthermore, very influential, periodic, but nevertheless predictable, catastrophic events which are part of the pattern are not accounted for in either hardiness maps or in climate data based on averages. The results suggest that simple geography and common sense may often provide the best framework for protection in the absence of adequate species presence data, and that strict adherance to a largely arbitrary system not supported by analyzed data may lead to substantial gaps and/or unnecessary duplication within a system of protected sites.

Literature Cited

Brown, D. M., G. A. McKay, and **L. J. Chapman.** 1980. The climate of southern Ontario. Environment Canada. Climatological Studies number 5. 67 pages.

Catling, P. M. 1995. The extent of confinement of vascular plants to alvars in southern Ontario. Canadian Field-Naturalist 109: 172–181.

Catling, P. M., and **V. R. Brownell.** 1995. A review of the alvars of the Great Lakes region: distribution, floristic composition, biogeography and protection. Canadian Field-Naturalist 109: 143–171.

Chapman, L. J., and **D. F. Putnam.** 1984. The physiography of southern Ontario, 3rd ed. Ontario Ministry of Natural Resources. 270 pages.

Ecological Stratification Working Group. 1995. A national ecological framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. 125 pages + map.

Gleason, H. A., and **A. Cronquist.** 1991. Manual of vascular plants of northeastern United States and adjacent Canada. Second Edition. The New York Botanical Garden, Bronx, New York. 910 pages.

Hills, G. A. 1959. A ready reference to the description of the land of Ontario and its productivity. Ontario Department of Lands and Forests, Divsion of Research, Maple. 142 pages.

Hills, G. A. 1961 [reprinted 1966]. The ecological basis for land-use planning. Ontario Department of Lands and Forests, Research Branch, Research Report 46. 204 pages.

Hubert, L. J. 1987. Assignment methods in combinatorial data analysis. Marcel Dekker, New York. 326 pages.

Land Resource Research Centre, Agriculture Canada. 1991. Plant hardiness zones in Canada. Land Resource Research Centre, Agriculture Canada, Ottawa. Map.

Legendre, L., and **P. Legendre.** 1983. Numerical ecology. Elsevir Scientific Publishing Co., New York. 419 pages.

Mantel, N. A. 1967. The detection of disease clustering and a generalized regression approach. Cancer Research 27: 209–220.

Newmaster, S. G., A. Lehela, P. W. C. Uhlig, and **M. J. Oldham.** 1998. Ontario plant list. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Forest Research Information Paper Number 123. 550 pages + appendices.

Pielou, E. C. 1984. The interpretation of ecological data. John Wiley and Sons, Toronto.

Riley, J. L., J. V. Jalava, M. J. Oldham, and **H. G. Godschalk.** 1997. Natural heritage resources of Ontario: bibliography of life science areas of natural and scientific interest in ecological site regions 6E and 7E, southern Ontario. First edition. Ontario Ministry of Natural Resources, Natural Heritage Information Centre, Peterborough. 156 pages. + 3 maps.

Rolfe, F. J. 1992. NTSYS-pc, Numerical taxonomy and multivariate analysis system, version 1.70. Exeter Publishing Ltd., Setauket, New York.

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Some Factors Affecting Density and Richness of Invertebrate Populations in the Near-shore Sediments of the St. Clair River, 1990–1995

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Harris, I. W. E. 1999. Some factors affecting density and richness of invertebrate populations in the near-shore sediments of the St. Clair River, 1990–1995. Canadian Field-Naturalist 113(4): 576–584.

Richness (the number of families/sample site) and density (the number of invertebrates/sq m) of benthic populations were measured from Lake Huron to the delta on Lake St. Clair. A sampling schedule was established over a six-year sampling period (1990-1995) to estimate yearly and seasonal effects between May and October (year-weeks 20-40), river flow rate, nutrient levels, sediment particle size distribution, vegetation density and downstream distance. Nitrogen and phosphorous concentrations in the shoreline sediment, used as measures of nutrients, were obtained from internal reports of the Ontario Ministry of the Environment and the U. S. Army Corps of Engineers and from personal correspondence. A total of twenty-six fixed sites were sampled; eight for three consecutive years (1990-1992), eight for three consecutive years (1993-1995) and ten for six consecutive years (1990-1995). Regression analysis showed richness and density of invertebrate populations to be positively associated with total phosphorous in the sediment, week number (20-40) and finer sediments. Richness was, in addition, negatively associated with the year of sampling (1990-1995). Evidence of long-term cyclic variations in density at the family level was found. Frequency of occurrence of most invertebrate orders increased with distance downstream.

Key Words: benthic invertebrates, St. Clair River, Lake Huron, Michigan, Ontario, sediments, nitrogen, phosphorous.

The St. Clair River has been designated by the International Joint Commission, in the Great Lakes Water Quality Agreement (revised by the Protocol of 1987)*, as one of the Areas of Concern in the Great Lakes system requiring remedial action to improve the ecosystem. Annex 17 of the revised Agreement specifies the research necessary to achieve the goals of the Agreement. Included in this annex under item (f) is the requirement to study benthic biota and ecosystem health. This study was undertaken to provide one of the baselines necessary for assessing the effectiveness of the remedial action taken.

The Ontario Ministry of the Environment (1987*, 1990*) and Environment Canada and the U. S. Environmental Protection Agency (1988*) have for many years investigated the status of the benthic invertebrate populations as an indicator of the quality of the St. Clair River ecosystem. In the present study, richness (or diversity) and density of these populations were used as measures of their health. Although high densities of one or two robust species indicates impairment, simultaneously high levels of both density and richness usually indicate a healthy population.

Study Site

The St. Clair River flows south from Lake Huron to a delta on Lake St. Clair in a channel 45 km long, up to 15 metres deep and varying in width from 200 metres to 1000 metres (Figure 1). The flow rate has been reported by Edsall et al. (1988*) to range between 3000 and 6700 cubic metres/sec. The flow is so massive and non-turbulent that cross-channel mixing has been detected only near the delta. Current velocity within about twenty metres of the shoreline is much lower than in the main channel and upstream eddies occur in some areas. When establishing sample sites, these areas of eddies were avoided.

On both the Michigan and Ontario shorelines outfalls of municipal and industrial wastewater are numerous. The industries on the Ontario shoreline are mainly petroleum refineries, petrochemical companies and fossil-fueled power plants. On the Michigan side industrial activity is less intense and made up of chemical production, fossil-fueled power generation and automotive parts assembly. The highest concentration of discharges from these activities is found in the part of the river from about four kilometres to fourteen kilometres downstream of the base point of this study at the entrance to the St. Clair River from Lake Huron (Figure 1).

Materials and Methods

Ten parameters were considered to be independent variables having the potential to exert a statistically significant effect on the richness and density of invertebrate populations in the river as follows:

year six years between 1990 and 1995 inclusive (years numbered 90-95)

*See Documents Cited section.

weekno sampling week (weeks numbered from the first week in January of each year).
riverkm nominal kilometres downstream of the base point near the Fort Gratiot Light in Lake Huron.
ms river surface flow rate at the time and point of sampling (metres/sec).
vg gravel content of sediment sample — volume percent of inorganic material having a particle size > 2.0 mm.
vs sand content of sediment sample — volume percent of inorganic material having a particle size between 2.0 mm and 0.2 mm.
vm mud content of sediment sample — volume percent of inorganic material having a particle size < 0.2 mm.
vv vegetation content of sediment sample — volume percent of macrophytic material on the 2 mm screen.
pugg total phosphorous content of sediment expressed as micrograms/gram.
nugg total nitrogen content of sediment expressed as micrograms/gram.

The volume percent variables are obviously interrelated since they must sum to one hundred. However, the analysis of the data by multiple linear regression identifies the statistically significant fractions of sediment particle size distribution. The dependent variables in the analysis of the data were:

richness number of invertebrate families found at each site.
density total of invertebrate individuals found at each site expressed as number/sq metre.

The geographic coordinates for all sample points are listed in Table 1. In the first three years, eighteen sites on the Ontario shoreline were sampled. At four locations, groups of three sites were established in an attempt to detect improvement in benthic populations with passage downstream as follows:

at 2.70 km, 2.72 km and 2.90 km
at 11.00 km, 11.02 km and 11.20 km
at 12.20 km, 12.22 km and 12.40 km
at 24.50 km, 24.52 km and 24.70 km

In 1992, after a review of the data, it was concluded that the two downstream sites at each of those four locations were redundant. Those sites were therefor transferred to the Michigan shoreline for sampling in the 1993-1995 period. In the subsequent final analysis, the data for the two upstream sites at each of the four initial locations were treated as duplicate measurements at 2.70 km, 11.00 km, 12.20 km and 24.50 km (Table 2).

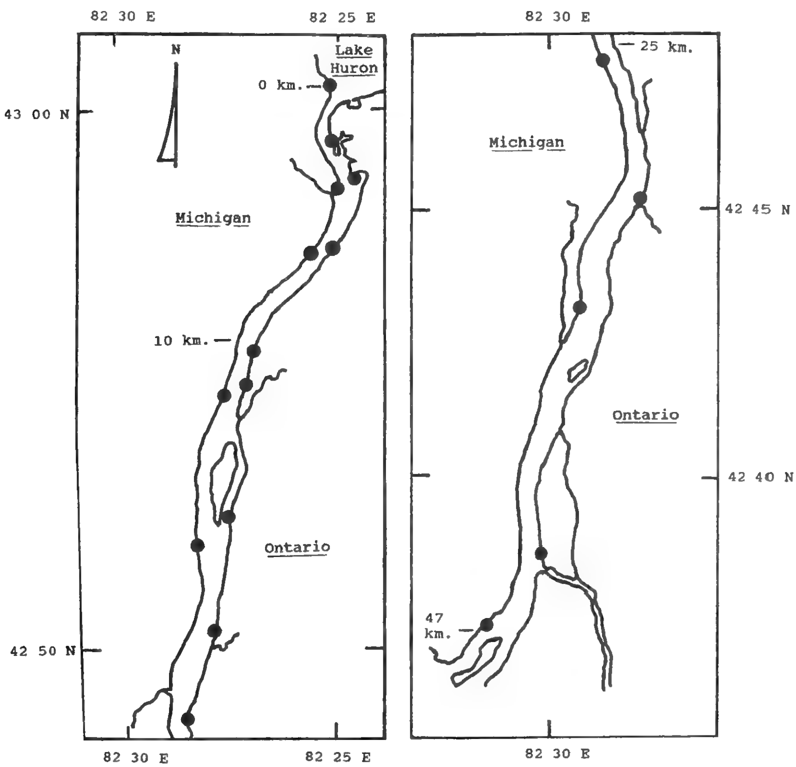

FIGURE 1. Sampling sites on the St. Clair River.

TABLE 1. Coordinates for sample points

	Latitude			Longitude			Nominal
Site No.	Deg.	Min.	Sec.	Deg.	Min.	Sec.	River km
001A	42	59	14	82	25	12	2.70
001B	42	59	13	82	25	12	2.72
001C	42	59	10	82	25	9	2.90
002	42	58	38	82	24	41	4.10
003	42	57	19	82	25	21	6.60
004A	42	55	30	82	27	9	11.00
004B	42	55	29	82	27	9	11.02
004C	42	55	26	82	27	11	11.20
005A	42	54	54	82	27	20	12.20
005B	42	54	53	82	27	20	12.22
005C	42	54	50	82	27	22	12.40
006	42	52	17	82	27	43	17.20
007	42	50	18	82	28	3	21.00
008A	42	48	32	82	28	43	24.50
008B	42	48	31	82	28	43	24.52
008C	42	48	28	82	28	43	24.70
009	42	45	12	82	28	2	30.80
010	42	39	0	82	30	23	43.20
101	43	0	32	82	25	16	0.00
102	42	58	25	82	25	8	4.50
103	42	57	20	82	25	46	6.80
104	42	54	42	82	27	50	12.60
105	42	51	39	82	28	24	18.40
106	42	47	35	82	28	42	26.20
107	42	43	12	82	29	21	35.00
108	42	37	26	82	31	21	46.40

Note: sites numbered 001-010 were on the Ontario shoreline.
sites numbered 101-108 were on the Michigan shoreline.

Samples were taken on the 2 metre depth contour once each year between May and October for the period 1990 through 1995. A schedule was established to ensure that samples were taken at each site over as wide a seasonal range as possible with a minimum of duplication as illustrated in Figure 2.

Sampling for invertebrate identification at each of the sites consisted of three grabs with a Petit Ponar dredge (0.0234 sq m) the contents of which were combined, washed on a screen with 0.5 mm mesh and preserved in 2% formaldehyde. The invertebrates present were separated by hand under magnification from the sediment debris, identified to the family level, counted and preserved in 70% isopropanol containing 0.2% glycerin. Empty shells and exuviae were not counted. Identification of invertebrates followed keys published by Merritt and Cummins (1988), Pennak (1989), Peckarsky et al. (1990) and Thorp and Covich (1991).

An archive of all specimens found, in vials coded with invertebrate identity, sample site, and sampling date has been deposited at the Zoology Department, University of Western Ontario (Robert Bailey). In addition, a copy of the entire database has been given to the university for incorporation into their records of invertebrate data.

At each sampling, a fourth grab of sediment was taken to characterize the distribution of particle sizes in the sediment. Following consultation with the Geology Department at the University of Western Ontario, an arbitrary decision was made to use screens with openings of 2 mm and 0.2 mm and a graduated cylinder to measure the volume percent of gravel, sand and mud respectively. When present, the volume percent of vegetation was estimated visually from the residue on the 2 mm screen and the volume percent gravel corrected accordingly. In addition, current velocity (metres/sec) at the surface was measured by timing the passage of a wooden float over a fixed distance.

Data on total nitrogen and total phosphorous in river sediment within about 500 m of each of the sampling sites for this study, were taken from data reported in several unpublished reports produced by Pope (1993*), the U. S. Army Corps of Engineers (1983* and 1991*), the Ontario Ministry of the Environment (1987*) and personal correspondence (T. B. Reynoldson, CCIW, Burlington, Ontario; P. B. Kauss, Ontario Ministry of the Environment, London, Ontario).

The arithmetic means shown in Table 2 are provided to illustrate trends. However, because of the

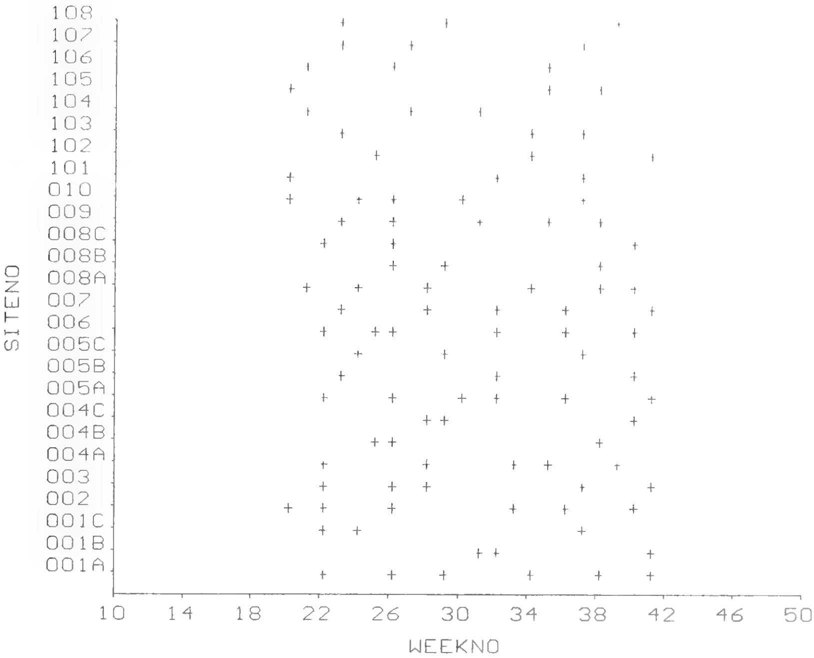

FIGURE 2. Sampling schedule for 1990-1995. 1** [101–108] sites are on the Michigan shoreline; 0*** [001A–010] sites are on the Ontario shoreline.

wide seasonal and yearly range over which the sampling for this study was done the standard errors associated with these means are large and essentially uninformative and have therefor been omitted. The regression analysis of the entire data base as discussed below, separates the variance for each of the statistically significant independent variables.

The data were analysed using software developed by the Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia, USA. (titled EpiInfo, Version 6). A diskette containing the entire database can be obtained from the author at no charge.

Results and Discussion

Because each site was sampled at different times yearly, richness and density of invertebrate populations found at a given sample site varied widely from year-to-year. However, means of the observations show consistent trends (Table 1) with distance downstream. The effects of season and year can not be discerned in this format.

Both richness and density increase rapidly in the first 10 km of the river. Richness remains at an approximately constant level of about 18 families/sample site beyond 15 or 20 km downstream of Lake Huron (Figure 3).

Because the density data exhibited a marked and highly variable positive skewness, the geometric means for each sample site have been plotted in Figure 4 in a log format. In addition to providing a reliable picture of the trend, this format shows more clearly the lower invertebrate density in the upper reaches of the river. An arithmetic format would show a trend line running from about 100 organisms/sq m at the head of the river to about 6000 organisms/sq m at the delta.

The plots in both Figures 3 and 4 are useful only for demonstrating trends. As discussed above, the sampling schedule used in this study results intentionally in wide variation in the results. For this reason tabulation of standard error for mean values or depiction of error bars on these plots is not useful.

Since the population of invertebrates was found to become more sparse toward the head of the river, three reaches of the river with approximately the same number of sample points were selected to illustrate the nature of these changes. The upstream reach is that part of the river from the base point in Lake Huron at the head of the river to a point 10 km downstream. Between 10 to 25 km and 25 to 45 km are designated as the midstream and the downstream reaches respectively. Data from both shorelines were combined. The characteristics of the benthic community in each of the three reaches are compared in Figure 5.

Because it is considered to be representative of a well-balanced community, the distribution curve of visual best fit for the downstream reach has been

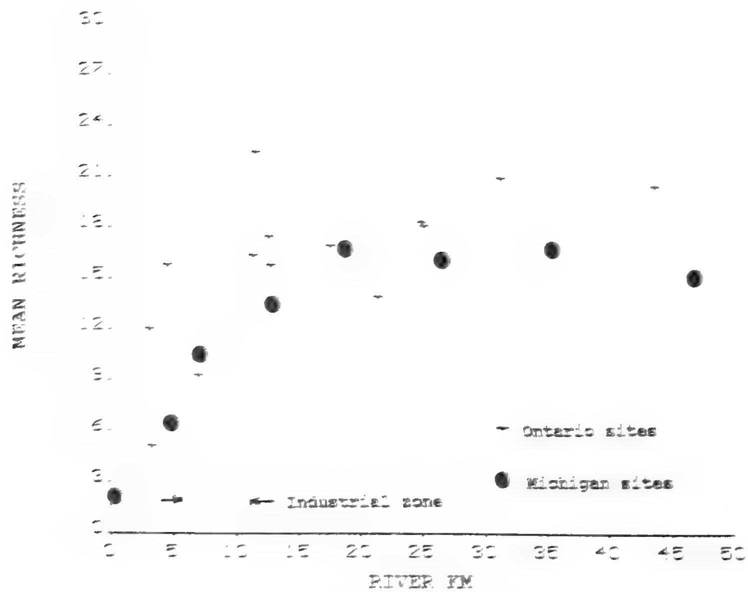

FIGURE 3. Variation of mean richness (number of families/site) of invertebrate populations with passage downstream (km).

included in the two upper panels of Figure 5 for ease of comparison. Log base 10 [(mean density)] is used as as the measure of relative frequency to emphasize variations of the less frequently encountered orders.

Oligochaeta appeared about equally in all three reaches. Diptera, Gastropoda, Bivalvia, Ephemeroptera, Cladocera and Turbellaria tended to be less frequent in the mid and upper reaches of the river. Amphipoda and Nematoda were less frequent in the midstream reach, while Hydracarina and Trichoptera were more frequent.

To establish the significance of the association of density and richness with the independent variables, multiple linear regressions were run repeatedly for both using the data from all sites for the entire six year period. Initially in each case, all the independent variables were included in the calculation. In successive runs, the dependent variable with least significance at the 95% level of confidence was eliminated until only those with significant B coefficients remained (Table 3). Both arithmetic and log form regressions were run to clarify the effect of the marked positive skewness of the density and richness data.

This method of analysis revealed the following regressions to be significant at the 95% level of confidence:

(i) Richness = 0.478(weekno) - 1.420(year) + 0.099(vm) + 0.039(pugg) + 121.4. Correlation coefficient: 53%

(ii) Log (Richness) = 0.016 (weekno) - 0.040 (year) + 0.004 (vm) + 0.003 (pugg) - 0.0003 (nugg) + 3.824. Correlation coefficient: 55%

(iii) Density = 16.25 (pugg) - 45.73 (vv) - 48.39 (vg) + 1060. Correlation coefficient: 36%

(iv) Log (Density) = 0.013 (weekno) - 0.008 (vg) + 0.004 (pugg) + 2.23. Correlation coefficient: 41%

Increased richness [equations (i) and (ii)] is thus found to be associated with increasing levels of total phosphorous, sampling later in the summer and finer particle size in the sediment. A negative coefficient for the year variable indicates a decline in richness of about one or two families/year at any given point in the river during the study period. The negative coefficient for total nitrogen in the log regression is anomalous since total nitrogen generally indicates increased nutrient levels and would therefore favour biological activity. The arithmetic regression, in which the nitrogen term does not appear, is considered to be a more reliable model than the log regression.

Increased density [equations (iii) and (iv)] is clearly associated with higher phosphorous levels and finer sediments. However, in the arithmetic regression, the negative association with the level of vegetation in the sediment is difficult to rationalize since organic matter provides nutrient and shelter for many types of invertebrates. The absence of a significant effect for the year of sampling in both density equations is noteworthy as discussed below. The log regression for density is considered the more reliable, not only because the correlation coefficient is slightly higher but also because the seasonal effect is significant and the anomalous negative vegetation effect is not.

TABLE 2. Arithmetic means of basic river characteristics and corresponding density and richness of invertebrate populations.

Down-River Distance (km)	Density (organisms /sq m)	Richness (families at each site)	Flow (metres /sec)	Sediment Character: Gravel (vol%) #	Sand (vol%) #	Mud (vol%) #	Veg. vol% #	P µg/g	N µg/g
0.0*	113	2.3	0.5	1	93	5	0	80	145
2.7	1758	12.2	0.1	10	69	6	13	100	100
2.9+	289	5.3	0.1	16	68	5	12	100	100
4.1	4291	16.0	0.1	3	55	20	21	272	561
4.5*	771	6.6	0.0	69	28	2	0	143	310
6.6	1146	9.5	0.7	73	14	7	4	186	596
6.8*	3318	10.6	0.1	0	58	10	24	225	695
11.0	2404	16.5	0.3	40	35	12	12	260	655
11.2+	2196	22.6	0.3	46	29	13	13	260	655
12.2	2867	17.6	0.4	19	45	9	26	279	504
12.4+	2958	16.0	0.5	24	42	11	23	279	504
12.6*	7436	13.6	0.2	0	67	23	8	200	420
17.2	2563	17.1	0.4	35	46	8	10	180	325
18.4*	5846	17.0	0.0	4	54	18	23	235	420
21.0	3155	14.1	0.1	8	62	21	5	223	545
24.5	3572	18.5	0.6	32	28	25	14	285	615
24.7+	2376	18.3	0.6	27	37	22	14	285	615
26.2*	3858	16.3	0.5	2	11	82	4	161	325
30.8	3761	21.1	0.3	7	18	63	9	271	713
35.0*	5704	17.0	0.2	1	53	27	17	265	540
43.2	5148	20.6	0.2	6	57	22	13	336	972
46.4*	8094	15.3	0.1	0	69	15	16	398	1454

+ Ontario shoreline - sampled 1990-1992
* Michigan shoreline - sampled 1993-1995
# percents may not sum to 100% because of rounding error

Current velocity, volume percent sand and distance downstream did not contribute significantly to any of these regressions at the 95% level of confidence. The sediment character of the river is mainly

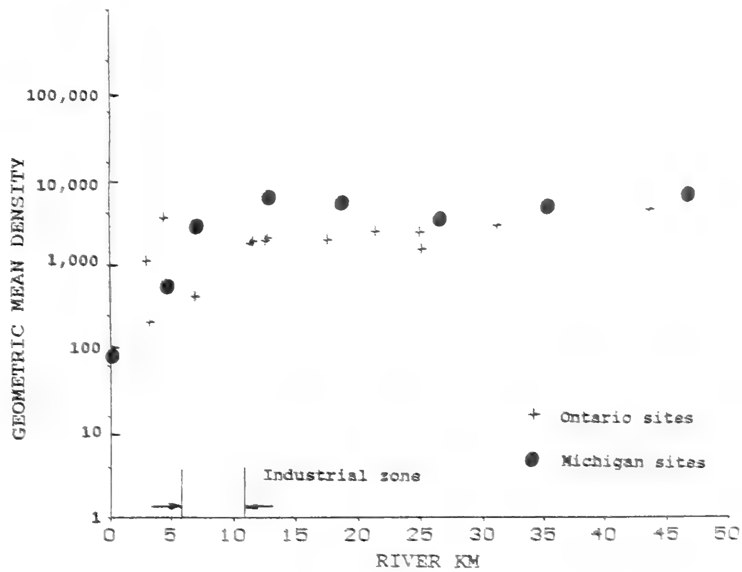

FIGURE 4. Variation of geometric mean density (organisms/square metre) of invertebrate populations with passage downstream (km).

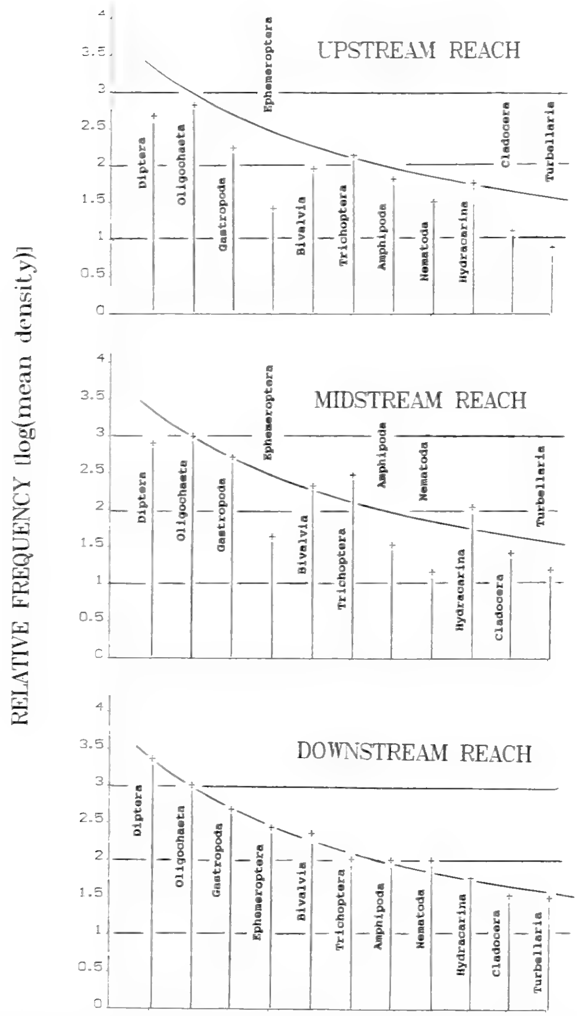

FIGURE 5. Relative frequency of invertebrate orders in three reaches of the St. Clair River.

attributable to the geology of the formation the river flows through. In progressing downstream, the river bed changes slope and passes through strata of different particle size. A further influence on the shoreline sediment character is the curves which occur at several points. On the outside of these curves the sediment is generally coarser because of more turbulence.

These regressions are only linear approximations of more complex, higher order functions identifying the major variables controlling richness and density of the invertebrate populations in the St. Clair River. For example, the positive coefficient for the "weekno" variable is probably attributable to the fact that the sampling period (May to October) coincides approximately with the normal seasonal growth period for benthic invertebrates. Had sampling been extended into the winter months when shoreline water temperatures are at or near freezing and ice scouring is common in some areas both richness and density would be expected to decline.

Similarly, the statistically significant negative coefficient for the variable "year" in the richness regressions is probably the net effect in the years of this study of the various cycles of increase and decline in the invertebrate families that make up the benthic population. Examples of these cycles are illustrated in Table 4. In the study period, Dreisseniidae and Caenidae exhibited almost complete cycles while Chironomidae and Gammaridae were observed in cycles longer than the six years recorded. Chironomidae appeared to be approaching a maximum while Gammaridae seemed to be near a minimum count. Although the numbers of many of

TABLE 3. Regression analysis for richness and density.

RICHNESS

Correlation coefficient: $r^2 = 0.53$

Variable	Mean	B coefficient	95% confidence Lower	95% confidence Upper	Std Error	Partial F-test
YEAR	92.50	-1.4205	-1.958	-0.883	0.271	27.46
WEEKNO	30.29	0.4785	0.336	0.621	0.072	44.11
VM	18.96	0.0993	0.050	0.149	0.025	15.80
PUGG	233.03	0.0386	0.026	0.051	0.006	36.13
Y-Intercept		121.389				

LOG (RICHNESS)

Correlation coefficient: $r^2 = 0.55$

Variable	Mean	B coefficient	95% confidence Lower	95% confidence Upper	Std Error	Partial F-test
YEAR	92.50	-0.0403	-0.0607	-0.0199	0.0103	15.34
WEEKNO	30.29	0.0161	0.0107	0.0214	0.0027	35.28
VM	18.96	0.0038	0.0019	0.0056	0.0009	16.48
PUGG	233.03	0.0027	0.0017	0.0038	0.0005	27.99
NUGG	550.25	-0.0003	-0.0006	-0.0001	0.0001	4.90
Y-Intercept		3.824				

DENSITY

Correlation coefficient: $r^2 = 0.36$

Variable	Mean	B coefficient	95% confidence Lower	95% confidence Upper	Std Error	Partial F-test
VG	21.46	-48.3867	-66.882	-29.892	9.326	26.92
VV	13.48	-45.7339	-78.436	-13.032	16.490	7.69
PUGG	233.03	16.2484	10.592	21.904	2.852	32.46
Y-Intercept		1060.082				

LOG (DENSITY)

Correlation coefficient: $r^2 = 0.41$

Variable	Mean	B coefficient	95% confidence Lower	95% confidence Upper	Std Error	Partial F-test
PUGG	233.03	0.0036	0.002	0.005	0.001	45.2
WEEKNO	30.29	0.0133	0.002	0.025	0.006	5.1
VG	21.46	-0.0078	-0.011	-0.004	0.002	20.6
Y-Intercept		2.229				

the invertebrate families found in the river were more or less stable during the study, it seems that periodically representatives of some families can be virtually absent from the river.

The lack of a significant effect of "year" in the density regressions suggests that the cycles of the families in the river merely change the richness. Members of other families proliferate to replace those individuals lost, thus maintaining the density appropriate for any given site.

Regardless of such qualifications and speculation, these regressions provide a good basis for compari-

TABLE 4. Year-to-year variation in the total count of individuals of some invertebrate families. All sites are combined for each year.

Year	Chironomidae	Gammaridae	Dreisseniidae	Caenidae
1990	184	203	0	6
1991	473	66	11	15
1992	937	43	44	87
1993	2104	20	437	117
1994	1853	24	28	60
1995	2362	21	4	33

son with future similar surveys. Generally, regressions with statistically significant B coefficients for clearly independent variables and correlation coefficients higher than forty or fifty are considered to be reliable representations of real phenomena.

Improvements in waste management practice by municipalities and industries in the St. Clair River Area of Concern should provide a more hospitable environment for reproduction and result in larger coefficients for the seasonal (weekno) variable for both the richness and density regressions. Further, this study indicates that to develop a clear picture of any changes in the health of the benthic community, a consistent multi-year study is necessary to account for the cyclic character of the invertebrate populations illustrated in Table 4.

While partly confirming studies like those undertaken by the Ontario Ministry of the Environment (Thornley 1985; Griffiths 1991; Pope 1993*), this study benefits in addition from the fact that it is a record for six consecutive years of the dynamics of the benthic community.

Furthermore, previous studies have tended to concentrate on examination of the benthos at and below the major municipalities and the industrial zone in the river. The finding in the present study, as illustrated by Figures 3 and 4, that the shoreline of the upper river is hospitable to fewer members of the benthic community than the shoreline below the municipal discharges of Sarnia and Port Huron and their industrial areas, provides a new perspective. This new view shows clearly the magnitude of error potential when attempting to assess the health of the benthic community and further shows that naturally occurring cycles and the location of collection sites can influence significantly estimates of the character of that community. This study clearly documents the dominant roles of fine sediments, phosphorous concentrations in sediment and a seasonal effect.

Acknowledgments

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Documents Cited (marked * where cited)

Edsall, T. A., P. B. Kauss, D. Kenaga, T. Kubiak, J. Leach, T., Nalepa, and **S. Thornley.** 1988. St. Clair River biota and their habitats: A geographic area report of the Biota Work Group, Upper Great Lakes Connecting Channels Study (typescript). Ontario Ministry of the Environment, London, Ontario, 73 pages.

Environment Canada and the U. S. Environmental Protection Agency. 1988. Upper Great Lakes Connecting Channels Study, Volume 2. 626 pages.

International Joint Commission. 1987. Great Lakes Water Quality Agreement of 1978 (amended 1987). 84 pages. [100 Ouelette Avenue, Windsor, Ontario, N9A 6T3.]

Ontario Ministry of the Environment. 1987. Data report on the 1985 St. Clair River bottom sediment survey.

Pope, R. J. 1993. Assessment of 1990 St. Clair River benthic-macroinvertebrate communities relative to sediment quality. Unpublished report prepared for the Ontario Ministry of the Environment, Water Resources Assessment Unit, London, Ontario. 124 pages.

U.S. Army Corps of Engineers. 1983. Dredging Sediment Survey (Contract by Analytical Research Group Inc.). 90 pages. [477 Michigan Avenue, Detroit, Michigan 48226.]

U. S. Army Corps of Engineers. 1991. Dredging Sediment Survey (Contract by Aquatec Inc., 55 South Park Drive, Colchester, Vermont, U. S. A., 05446), 13 pages. 477 Michigan Avenue, Detroit, Michigan 48226.

Literature Cited

Griffiths, R. W. 1991. Environmental assessment of the St. Clair River as reflected by the distribution of benthic macroinvertebrates in 1985. Hydrobiologia 219: 143–164.

Merritt, R. W., and **K. W. Cummins.** 1988. An introduction to the aquatic insects of North America (2nd edition). Kendall/Hunt Pubiishing Co., Dubuque, Iowa. 722 pages.

Pennak, R. 1989. Fresh water invertebrates of the United States (3rd edition). John Wiley and Sons, Toronto. 628 pages.

Peckarsky, B. L., P. R. Frassinet, M. A. Penton, and **D. J. Conklin, Jr.** 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, New York. 442 pages.

Thornley, S. 1985. Macrobenthos of the Detroit River and St. Clair Rivers with comparisons to neighbouring waters. J. Great Lakes Research 11: 290–296.

Thorp, J. H., and **A. P. Covich.** 1991. Ecology and classification or North American freshwater invertebrates. Academic Press Inc., Toronto. 911 pages.

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Benthic Macroinvertebrate Communities and Water Quality of Headwater Streams of the Oak Ridges Moraine, Southern Ontario

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Maude, Stephen H., and Joanne Di Maio. 1999. Benthic macroinvertebrate communities and water quality of headwater streams of the Oak Ridges Moraine, southern Ontario. Canadian Field-Naturalist 113(4): 585–597.

The Oak Ridges Moraine is a prominent physiographic feature of southern Ontario that functions as the source area for many streams. It has been the focus of increased attention recently because of concern about its protection in the face of rapid urban growth in the Greater Toronto Area. In 1992, we undertook a survey of 28 sites from relatively undisturbed streams of the Oak Ridges Moraine; prior to our work, these regional-scale data were lacking. Our survey comprised the collection of physical, chemical, and biological data, with emphasis on rapid bioassessment of benthic macroinvertebrate communities. The sites sampled were small, cold, well-oxygenated, spring-fed, headwater streams that supported diverse assemblages of benthic macroinvertebrates, including a number of sensitive taxa. At most sites, water quality was better than the water quality standards normally applied to surface waters. Differences among sites in water temperature, total taxon richness, and the concentrations of key chemical variables may reflect varying degrees of influence from springs. We used the approach of Novak and Bode (1992) to develop an Oak Ridges Moraine community model as a tool for evaluating observed stream conditions based on the composition of the benthic macroinvertebrate communities from the 28 reference sites. This characterization of reference conditions provides regional context for evaluating information related to headwater streams of the Oak Ridges Moraine.

Key Words: headwater streams, regional reference sites, Oak Ridges Moraine, benthic macroinvertebrates, water quality, Ontario.

The Oak Ridges Moraine is one of the most distinctive physiographic features of southern Ontario. It is a prominent ridge of knob and kettle topography, comprised of drift deposited during the Wisconsinan glaciation, that stretches in an east - west direction for approximately 160 km through the centre of south-central Ontario, just north of the City of Toronto. Toronto and surrounding Regional Municipalities are known collectively as the Greater Toronto Area (GTA). The portion of the Oak Ridges Moraine within the GTA is approximately 90 km long and varies in width from 4 - 24 km (Intera Kenting 1990).

In recent years, the Oak Ridges Moraine has received greater local attention because of concern about its protection in the face of rapid urban growth within the GTA (RCFTW 1990; MNR et al. 1991; ORMTWC 1994). Over four million people live in the GTA and this population is expected to increase by at least two million people over the next 20 - 30 years. Presently, the Oak Ridges Moraine is still largely rural. Because of its irregular, hummocky topography it has not been the focus of extensive urbanization to date, although some significant urban development areas do exist, primarily along major transportation corridors. It is anticipated that continued population growth in the GTA will place considerable pressure on the Oak Ridges Moraine for land use change and natural resource exploitation.

The Oak Ridges Moraine is the source area for 21 major watercourses and forms the divide between streams flowing south to Lake Ontario and streams flowing north to Lake Simcoe and the Trent-Severn Waterway. It features the largest concentration of headwater streams in the GTA (ORMTWC 1994; Chapman and Putnam 1984). Headwater streams rely on flow contributed from groundwater and inputs of energy from the terrestrial system. Headwaters represent the maximum interface between the aquatic and terrestrial systems (Vannote et al. 1980); relative to higher-order streams further downstream, a headwater (i.e. low-order, orders 1 - 3) stream has a relatively small network of drainage basin that contributes to a given channel reach. This intimate relationship between drainage basin and stream makes headwater streams especially sensitive to land disturbance.

A major difficulty faced by those evaluating proposed land developments is the paucity of information pertaining to the water quality and ecology of streams of the Oak Ridges Moraine. Proponents of land development proposals are required to undertake environmental studies and submit their findings for review by government agencies, however, it is difficult to assess these site-specific data without the context of regional information. The utility of documenting regional reference conditions is becoming increasingly recognized in water resource management and examples exist of the successful use of regional reference sites for rivers and lakes in a number of jurisdictions in the

USA (Gallant et al. 1989; Hughes et al. 1994; Whittier et al. 1988). Regional reference sites are useful for estimating ranges of attainable ecological condition, evaluating temporal and spatial changes in ecological integrity, predicting and assessing impacts, setting targets for remedial work, and developing biological criteria for watercourses (Hughes 1995; Hughes et al. 1986; Gerritsen 1995).

In light of the above, the collection of water quality and biological information for streams of the Oak Ridges Moraine is of considerable importance. Our primary objective was to document reference conditions on the Oak Ridges Moraine by conducting field sampling to characterize the biology, chemistry, and physical habitat of relatively undisturbed streams.

Methods

The study area comprised that portion of the Oak Ridges Moraine within the GTA. Preference in sampling site selection was given to first- or second-order streams that had well-defined riffle areas and which drained lands relatively undisturbed by development. Candidate sites were identified initially using 1:50 000 topographic maps and field reconnaissance was then undertaken to ensure that the sampling sites met the above criteria. Our intent was to obtain a spatially broad snapshot of conditions across the Oak Ridges Moraine, however, in some locations, especially near rapidly urbanizing areas in the central portion of the Moraine, acceptable undisturbed sites could not be found.

From 20 May to 11 August 1992, chemical and benthic samples were collected from 28 sites located across the Oak Ridges Moraine on rain-free days (Table 1, Figure 1). Initially, 30 sites were sampled. After sampling, it was discovered that there were significant areas of developed land upstream of site 7 and site 10. Because the two sites had potentially been impacted by these developments, these sites were excluded from further consideration, however, the original site numbering (1 - 30) has been retained. Each site was sampled once. For each site sampled, geographic coordinates, elevation, distance from the stream source to the sampling point, and stream gradient were determined from the 1:50 000 topographic maps. At each site, stream discharge, dissolved oxygen, and temperature were measured. Water temperature was taken as a single-point-in-time reading, but always between 1130 - 1530 h. Three replicate water samples were taken from mid-stream; these were stored on ice and delivered to the Ministry of the Environment's (MOE) central labo-

TABLE 1. Streams sampled on the Oak Ridges Moraine. See Figure 1 for map of site locations.

Site number	Stream name	Latitude	Longitude	Date sampled
1	Holland River	43°58'18"N	79°35'15"W	20 May 1992
2	Uxbridge Brook	44°05'07"N	79°05'10"W	21 May 1992
3	East Duffins Creek	44°00'17"N	79°04'06"W	26 May 1992
4	Little Credit River	43°50'35"N	79°55'15"W	28 May 1992
5	Pefferlaw Brook	44°06'32"N	79°15'05"W	1 June 1992
6	Wilmot Creek	44°02'40"N	78°39'00"W	2 June 1992
8	West Duffins Creek	44°00'40"N	79°11'08"W	8 June 1992
9	Humber River	43°55'17"N	79°54'40"W	9 June 1992
11	Black River	44°06'10"N	79°21'20"W	11 June 1992
12	Mount Albert Creek	44°06'35"N	79°19'52"W	11 June 1992
13	East Cross Creek	44°06'05"N	78°45'58"W	15 June 1992
14	Vivian Creek	44°04'41"N	79°17'49"W	16 June 1992
15	East Oshawa Creek	44°00'59"N	78°52'56"W	18 June 1992[a]
16	Centreville Creek	43°54'52"N	79°51'50"W	22 June 1992
17	Ganaraska River	44°02'43"N	78°32'55"W	23 June 1992
18	Bowmanville Creek	44°02'43"N	78°43'35"W	29 June 1992
19	Nonquon River	44°03'24"N	79°02'00"W	30 June 1992
20	Beaverton River	44°05'46"N	79°04'35"W	2 July 1992
21	Soper Creek	44°01'01"N	78°41'10"W	8 July 1992
22	Lynde Creek	44°00'53"N	79°01'28"W	16 July 1992
23	Mackie Creek	44°01'40"N	78°42'42"W	22 July 1992
24	Humber River	43°55'54"N	79°54'09"W	24 July 1992
25	Ganaraska River	44°02'29"N	78°32'39"W	27 July 1992
26	Uxbridge Brook	44°04'44"N	79°06'01"W	28 July 1992
27	Centreville Creek	43°52'59"N	79°53'35"W	5 August 1992
28	Wilmot Creek	44°02'06"N	78°38'29"W	6 August 1992
29	Ganaraska River	44°03'39"N	78°32'36"W	10 August 1992
30	Pefferlaw Brook	44°04'50"N	79°12'56"W	11 August 1992

[a]Field measurements and benthic collection 18 June; chemistry re-sampled 8 July due to laboratory error with original samples.

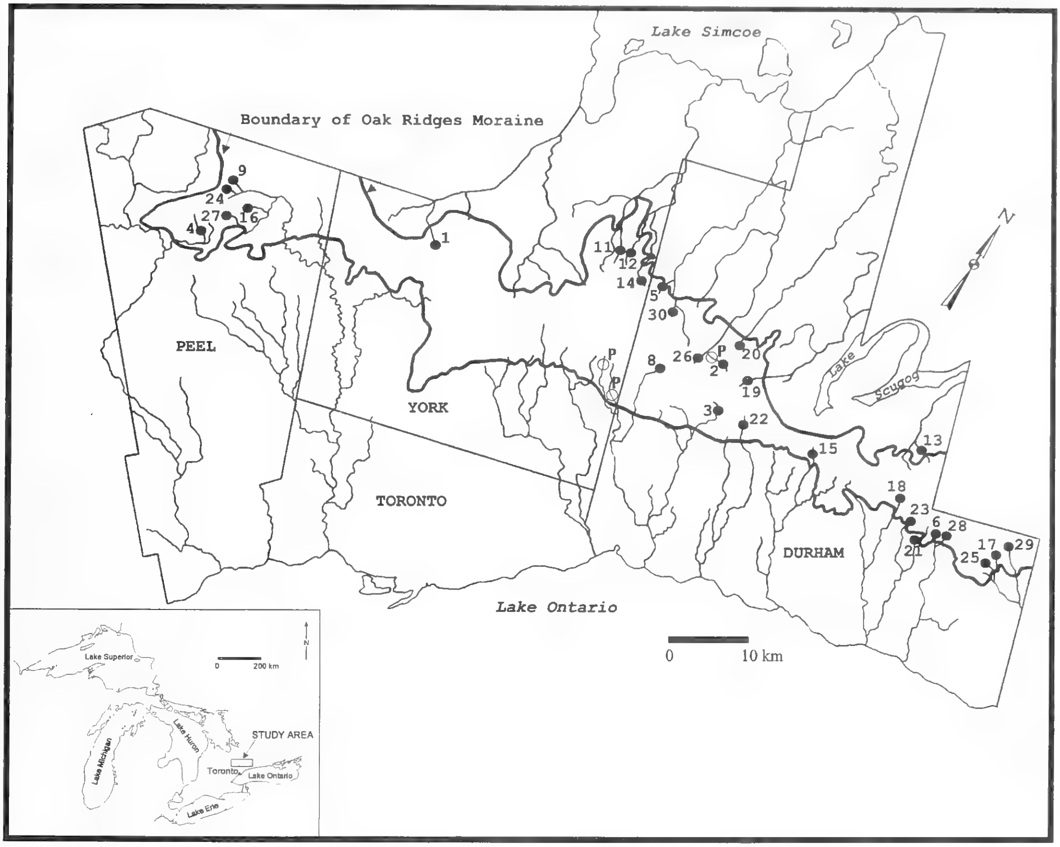

FIGURE 1. Map of the study area, showing the locations of sites sampled on the Oak Ridges Moraine. See Table 1 for key to site numbers. ◯ **P** denotes locations of the three Provincial Water Quality Monitoring Network stations referred to in text.

ratory, usually within 24 hours of sampling, and analyzed there using standard methods (MOE 1983). Two investigators each independently collected a benthic sample measuring approximately 1 m^2 in a riffle area using the kick sampling method; rocks and sediment on the bottom of the stream were disturbed by foot causing dislodged organisms to drift downstream into a 900 Fμ mesh D-frame net. The two samples were placed into white plastic trays in the field, examined, and the macroinvertebrates were picked from the debris and preserved in 70% ethanol. Picking continued until a total of at least 100 individuals had been collected at the site.

For each site, the two benthic macroinvertebrate samples were combined, sorted, and individuals identified to the lowest taxonomic level that could be readily determined: to species for hydropsychids; to genera for Odonata, Coleoptera, Megaloptera, Hemiptera, Plecoptera, Ephemeroptera, remaining Trichoptera, most Diptera, Amphipoda, Isopoda, and Decapoda; to subfamily or tribe for Chironomidae; to family for Simuliidae; to class for Oligochaeta, Gastropoda, Turbellaria, Hirudinea, and Bivalvia; to order for Diplopoda; and to subcohort for Hydrachnidia. Published keys used to identify the organisms included Peckarsky et al. (1990), Pennak (1978), and Merritt and Cummins (1978); unpublished keys (R. J. Mackay, University of Toronto, personal communication) were used to identify hydropsychids and chironomids.

There are a number of metrics or indices that can be calculated to describe the benthic macroinvertebrate communities sampled using rapid bioassessment techniques (Plafkin et al. 1989). The various metrics provide summary measures of richness, abundance, diversity, tolerance to organic pollution, or functional feeding groups (Resh and Jackson 1993). We used the benthic macroinvertebrate data to calculate the following metrics for each site: total taxon richness (total number of distinct taxa), percent contribution of major insect orders to total abundance, EPT taxon richness (the number of distinct taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera), and Hilsenhoff's Biotic Index. In calculating total and EPT taxon richness, we counted the *Hydropsyche* species as one taxon to be consistent with the predominately generic-level taxonomy used for other groups.

Hilsenhoff's Biotic Index is a numerical scale developed for use in shallow riffles to evaluate the relative degree of organic or nutrient pollution; biotic index scores range from 0 - 10, with 0 being the least polluted and 10 being the most polluted. Scores are calculated by multiplying the number of individuals collected from a taxon by the pollution tolerance value (0 - 10) for that taxon, summing these products for all taxa, and dividing by the total number of individuals collected (Hilsenhoff 1982; Hilsenhoff 1987). Hilsenhoff's biotic index is widely used, but comparison of index scores across studies must be approached cautiously because index scores are affected by factors that vary from study to study, such as taxonomic resolution and the season of sample collection. We used the pollution tolerance values suggested by Bode (1988) and Hilsenhoff (1987; 1988) according to the most detailed level of taxonomy we had available and did not adjust the biotic index scores for season. Hemiptera and Diplopoda were not included in the calculation of the biotic index because pollution tolerance values for these taxa were not available.

Correlation analysis (Sokal and Rohlf 1969) was used to explore relationships between variables. Total taxon richness and EPT taxon richness were included in the analysis as biological variables. The percent contribution of orders to total abundance and Hilsenhoff's biotic index were excluded because of the problem of compounded variability associated with ratios (Green 1979). Inherent to a one-time regional survey such as this study is the simultaneous influence of both temporal and spatial variation. To evaluate temporal variation, sampling date was included as a variable in the correlation analysis. All variables were transformed using a log(x + 1) transformation prior to analysis.

As a biological reference tool, we developed a preliminary community model based on the mean composition of the benthic macroinvertebrate communities of the Oak Ridges Moraine reference sites. Novak and Bode (1992) employed this approach in their work on shallow freshwater streams in New York State. An ideal, community model is described based on the mean percentage contribution to total abundance by seven organism groups: Chironomidae, Trichoptera, Ephemeroptera, Plecoptera, Coleoptera, Oligochaeta, and Other, a group comprised of all remaining taxa.

Results and Discussion

The watercourses sampled were small, cold, well-oxygenated, spring-fed, headwater streams. Most

TABLE 2. Observed ranges of physical and chemical variables from 28 Oak Ridges Moraine (ORM) reference sites.

Variable	Units	ORM range
Elevation	m	213 - 351
Distance from source	km	0 - 4.1
Gradient	m/km	5 - 64
Water temperature	°C	9 - 21
Dissolved oxygen	mg/L	7.1 - 11.4
Discharge	L/s	1 - 129
Conductivity	µmho/cm	262 - 552
Hardness	mg/L	136 - 263
Alkalinity	mg/L	125 - 236
pH	pH units	8.1 - 8.5
Turbidity	Formazin units	0.8 - 14.5
Calcium	mg/L	39 - 78
Magnesium	mg/L	8 - 19
Sodium	mg/L	2 - 25
Potassium	mg/L	0.5 - 1.3
Chloride	mg/L	2 - 48
Sulphate	mg/L	12 - 34
Total phosphorus	mg/L	<0.002 - 0.075
Filtered reactive phosphate	mg/L	<0.0005 - 0.0223
Total Kjeldahl nitrogen	mg/L	0.04 - 0.52
Ammonia nitrogen	mg/L	<0.002 - 0.065
Nitrate nitrogen	mg/L	<0.01 - 4.5
Nitrite nitrogen	mg/L	<0.001 - 0.037
Dissolved organic carbon	mg/L	1 - 5
Dissolved inorganic carbon	mg/L	30 - 54

sites were located within < 4 km of the stream's source, in reaches with very steep gradients (Table 2). Water temperatures were between 9 - 21°C at the time of measurement. Continuous measurements of water temperature indicate that, in summer, shaded, spring-fed streams in the study area exhibit a daily temperature fluctuation of < 3°C, with temperature maxima usually occurring in the afternoon (S. H. Maude, unpublished data). The water temperatures measured in this study are likely within < 2°C of maximum daily values. Observed dissolved oxygen levels ranged from 73 - 113% saturation, well above the MOE's Provincial Water Quality Objective for cold-water biota of 54% saturation (MOEE 1994). Most sites had dissolved oxygen levels close to 100% saturation. Measured stream discharges ranged from 1 - 129 L/s.

All of the sites were characterized by hard, alkaline water with high concentrations of dissolved salts, characteristic of watercourses draining calcareous soils (Table 2). Calcium was the dominant cation, accounting for 61 - 78% of the total cations in solution. Bicarbonate, as estimated from measured alkalinity, accounted for 70 - 91% of the total anions in solution. Chloride constituted 1 - 23% of the total anions and was important at only a small number of sites. At seven sites chloride accounted for > 10% of the total anions; all but one of these had sodium as a prominent cation, suggesting that these sites may have been influenced by salt contamination. Because elevated concentrations of chloride are associated with the use of salt for road de-icing, chloride concentration can serve as an indicator of urbanization (Williams et al. 1997). In a study of springs along an urban - rural transect in the GTA, Williams et al. (1997) found a strong relationship between the composition of macroinvertebrate communities and chloride, based on a range of chloride concentrations from 8 - 1149 mg/L.

Site mean pH ranged from 8.1 - 8.5, which is within the acceptable provincial limits for the protection of aquatic life (MOEE 1994). At three sites mean total phosphorus concentrations exceeded the MOE's Interim Provincial Water Quality Objective of 0.03 mg/L for the elimination of excessive plant growth in rivers and streams (MOEE 1994). With the exception of three sites, filtered reactive phosphates were found only in minute concentrations. Sixteen sites had mean ammonia nitrogen concentrations less than the detection limit of 0.002 mg/L. All samples collected had un-ionized ammonia concentrations well below the Provincial Water Quality Objective of 0.02 mg/L established for the protection of aquatic life (MOEE 1994). All of the measured concentrations of nitrite were < 0.06 mg/L, the recommended federal guideline for the protection of aquatic life (CCREM 1987).

Observed chemical concentrations were generally at the low end of the ranges recorded for three long-term background stations on the Oak Ridges Moraine sampled as part of the MOE's Provincial Water Quality Monitoring Network, a network of stations for the routine collection of riverine water chemistry samples (Figure 1). Samples have been collected at these stations approximately monthly since the 1970s. Higher ranging chemical concentrations at these long-term stations are due to influences of season, precipitation, and progressive land use change over time. For instance, chloride concentrations at these three stations increased 2.5× between the mid-1970s and the early 1990s, suggesting that some land use impacts have occurred. The three stations are located 1.7 km, 4.6 km, and 6.8 km downstream from their respective stream sources and all have some degree of present-day disturbance upstream.

Benthic macroinvertebrates collected comprised 93 different taxon, with total taxon richness ranging from 11 - 30 (Table 3). Oligochaetes and gastropods were found at half or more of the sites. However, the non-insect taxa (Oligochaeta, Amphipoda, Gastropoda, Hydrachnidia, Diplopoda, Turbellaria, Hirudinea, Isopoda, Decapoda, and Bivalvia) and Anisoptera, Zygoptera, Megaloptera, and Hemiptera did not contribute greatly to the total number of individuals collected. Individuals of these taxa made up only 8% of all the organisms collected. The main insect orders, namely, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera and Diptera comprised 81 - 100% (mean = 92%) of total abundances at the sites. Overall, the most abundant order was Diptera, representing 30% of the total individuals collected.

Insect taxa found at > 50% of the sites included the riffle beetle *Optioservus*, the stonefly *Amphinemura*, the mayflies *Baetis* and *Paraleptophlebia*, the caddisflies *Hydropsyche*, *Rhyacophila*, *Neophylax*, and *Lepidostoma*, and the dipteran families Simuliidae, Chironomidae, and Tipulidae. *Optioservus*, *Amphinemura*, *Baetis*, Simuliidae, and Chironomidae (Orthocladiinae) occurred at high relative abundances (i.e. > 25% of individuals collected) at some sites. *Baetis* was the single taxon most frequently and abundantly encountered. The mayfly *Epeorus* was found at only three sites, but in high abundance at one of these. The caddisfly *Dolophilodes* occurred at high relative abundance at two of 12 sites. Sixteen taxa were unique, each being found at only one site. These were found in very low abundances, with the exception of the caddisfly *Helicopsyche* at site 8 where 75 individuals were collected.

Values of EPT taxon richness (defined here as the total number of *genera* of mayflies, stoneflies, and caddisflies) ranged from 4 - 14. Hilsenhoff's biotic index scores ranged from 1.33 - 5.26, spanning Hilsenhoff's (1987) excellent (11 sites), very good (12 sites), and good (five sites) water quality categories. The excellent, very good, and good

TABLE 3. Relative abundance of benthic macroinvertebrates collected from sites on the Oak Ridges Moraine. Symbols denote the percent contribution of taxa to the total abundance at each site: + = present (< 1%), L = Low (1% - 10%), M = Moderate (10% - 25%), H = High (> 25%).

Taxon	Pollution Tolerance Value	Site Number																											
		1	2	3	4	5	6	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
ANISOPTERA																													
Aeshnidae	3																												
Boyeria	2							+					L								+		+	L	+				
Gomphidae	1																												
Hagenius	1																	+											
Gomphus	5																							+	+				L
Cordulegastridae	3																												
Cordulegaster	3					L								+	L	L		L	+		L		L	L	+	+			L
ZYGOPTERA																													
Calopterygidae	5																												
Calopteryx	5												L										+						+
COLEOPTERA																													
Dytiscidae	5																												
Hydacticus	5	+																	L										
Agabus	5																+	+	+						+				
Hydroporus	5		+																						+				
Dryopidae	5																												
Helichus	5	L	+				+			L		+			L			+							+		+	+	
Elmidae	4																												
Stenelmis	5	L						M	L							L		M			L		M	M	+				L
Optioservus	4	M	+	L	L	L		H	M	M		L	L	L	L	M	L	L	+		M	+	M	L	+				L
Macronychus	4								L												L								
Promoresia	4												L										+						L
Hydrophilidae	5																												
Crenitis	5		+																										
Hydrobius	5																						+						
Haliplidae	5																												
Haliplus	5												+																
Psephenidae	4																												
Psephenus	4																	M					+	+					
MEGALOPTERA																													
Sialidae	4																												
Sialis	4	+			+								L	+	+					+									
Corydalidae	0																												
Nigronia	0							L		+			+					L			+		L						

(Continued)

TABLE 3. *Continued.*

Taxon	Pollution Tolerance Value	Site Number																											
		1	2	3	4	5	6	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
HEMIPTERA																													
Gerridae																													
Gerris		+												+															+
Rheumatobates																											+		
Veliidae																													
Microvelia		L												+					+					L					
Rhagovelia																		L			+		+	+	+				L
Hebridae																													
Merragata																+													
PLECOPTERA																													
Nemouridae	2																												
Amphinemura	3	H	L	+		L	L		L	L	L		+	L			L		L	L		L					+	H	
Nemoura	1	+	M														L												
Perlodidae	2																												
Clioperla	1	L																											
Isoperla	2				L		+								+							L			+		M		
Leuctridae	0																												
Leuctra	0		L								+			L	+		L		+	L		+				+		M	
Chloroperlidae	1																												
Haploperla	1		+				+					L					L			L		L				+	L		
Perlidae	1																												
Agnetina	2			L												L								+					
Paragnetina	1			L					+																				
EPHEMEROPTERA																													
Baetidae	4																												
Baetis	4		L	L	H	L	H	L	L	M	M	H		H	H	L	L	L	L	H	L	H	L	M	H	M	M	+	+
Heptageniidae	4																												
Epeorus	0			H	M							+																	
Stenonema	3								L	+								+			+		L						
Stenacron	7																	+					+			L			
Leptophlebiidae	2																												
Paraleptophlebia	1			L		M	L	+	L			L		M	M	+		L		+	M	+	L						
Ephemerellidae	1																												
Ephemerella	1			L	L	L	+										+									L			
Drunella	0			M																L		L							
Attenella	1		+																								L		

(Continued)

TABLE 3. *Continued.*

Taxon	Pollution Tolerance Value	Site Number 1	2	3	4	5	6	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Oligoneuridae	2																												
Isonychia	2																				+								
TRICHOPTERA																													
Hydropsychidae	4																												
Hydropsyche	4																												
betteni	6	L						L	L				L			L		L						+	L				M
slossonae	4					L		L					+	L	+	L				+									L
sparna	6			L		L		L	L				L	L		L		M	+	+				L	+		+		+
Diplectrona	0	L								+				L	M						+			L	+				
Parapsyche	0		L				M				L	+					+		+	+		M				L	L	L	
Cheumatopsyche	5							L	L				L	+		+		L			L		M			+			M
Rhyacophilidae	0																												
Rhyacophila	0	L	L		L		L	+		+	L	L		L	L	+	L		+	L		L			L		M		+
Uenoidae	3																												
Neophylax	3	M	+	L	L	M	M	+	L	L	M			L		+	+	+									L		
Limnephilidae	4																												
Limnephilus	3	L	L			L					L	+	L		+										+	L			
Psychoglypha	0					L				L	L	L	L							+				+	L	+			
Pycnopsyche	4					L		+		L			L	L	M						+		+	+		+			
Asynarchus	6															+													
Goera	0																							L		L		+	
Philopotamidae	3																												
Wormaldia	0			+																				L			+		
Dolophilodes	0			L								+		+	L	L	H		L	M		L		+	L			H	
Chimarra	4																	M			L		L	+					
Glossosomatidae	0																												
Glossosoma	0			L			L	+						+						L				L		+	M	L	
Protoptila	1			L												+													
Lepidostomatidae	1																												
Lepidostoma	1					L				L	+	L	M	+	L	+			L	L		+		L	L	+		+	
Helicopsychidae	3																												
Helicopsyche	3							M																					
Hydroptilidae	4																												
Hydroptila	6											L								+									
DIPTERA																													
Simuliidae	6				+		L	+	+	M	+		+	+	L	H	M	+	H	L	L	H	+	M	H	+	+	L	L

(Continued)

Taxon	Pollution Tolerance Value	Site Number																											
		1	2	3	4	5	6	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Chironomidae	6																												
Orthocladiinae	5	M	H			M	+	M	M	L	H	M	H	L	L	L	M	L	L	L	L	L	L	L	L	L	L	L	M
Chironominae	6																												
(Tanytarsini)	6		+	L		L	L			+		L	L		+	+				+	L	+		L		M	L		L
(Chironomini)	8										+	+	L		L						L		L				L		
Tanypodinae	7					L	+			L	L	L	L	L		L	+	L	+	+	L	+	L	L			L		L
Tipulidae	3																												
Dicranota	3	L	+				L	+		L	L	L		L	+		L	+	L	L	M	L	L	L	L	L	+	L	L
Pedicia	6		+																										
Hexatoma	2			L			+	+	+			+		+	L	M	+	L		L		+		L		M		+	
Tipula	4			L		+			+	+			+	+				L		+				+			+		L
Antocha	3				L	+		L				L								+									
Pseudolimnophila	2								+									L			L								
Limnophila	3											+																	
Oromosia	3																										L	L	
Molophilus	3																											+	
Tabanidae	6																												
Chrysops	6					L			+	+	+		L		+			L					M		L				L
Empididae	6																												
Chelifera	6		+																								L		
Hemerodromia	6																												+
Dixidae	1																												
Dixella	1																L							+		+			
Psychodidae	10																												
Pericoma	4																		+										
Athericidae	2																												
Atherix	2												L							+		+	+						
OLIGOCHAETA	8	L	L			L	L		L	L	L	+	+	+	L	+	L		+	+		L	L		L	L	+	+	+
AMPHIPODA																													
Gammaridae	4																												
Gammarus	4								L	L													L						L
GASTROPODA	8	+	L					+		+	+	L	+				+		+		L	+		L	L				L
HYDRACHINIDIA	6				+	+	L				L	M				L	+		L	L	+	L				+	+		
DIPLOPODA			L				L				+	+		+			+		+								+		
TURBELLARIA	6																										+		
HIRUDINEA	6									L													+		L				L

(Continued)

TABLE 3. *Concluded.*

Taxon	Pollution Tolerance Value	Site Number 1	2	3	4	5	6	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
ISOPODA																													
Asellidae	8																												
Caecidotea	8	+								L		+								+					L		+		
DECAPODA																													
Cambaridae	6																												
Cambarus	6													L															
Orconectes	6																	+											
BIVALVIA	6												L							+	+			+					L
Summary																													
taxa richness*		20	21	18	11	20	20	19	19	24	19	26	25	27	23	22	22	26	22	28	25	22	27	30	26	22	27	16	25
EPT richness*		8	9	14	6	10	10	9	8	9	9	11	7	13	11	11	10	8	8	14	8	11	7	12	9	13	11	8	4
Hilsenhoff Biotic Index		3.46	3.56	1.33	3.21	3.13	2.84	4.24	4.38	4.49	4.17	4.06	4.65	3.22	3.18	4.48	3.16	4.23	4.55	2.59	3.99	3.99	4.90	4.29	4.72	3.64	2.86	1.98	5.26

**Hydropsyche* species pooled as one taxon – see text.

categories indicate, respectively, no apparent organic pollution, possible slight organic pollution, and some organic pollution (Hilsenhoff 1987). Sites in the latter two categories may be exhibiting natural enrichment. We suspect that the biotic index scores from some of our sites may be inflated due to the lack of detailed taxonomy and consequent use of more-general pollution tolerance values for simuliids, chironomids, and oligochaetes, and also perhaps due to the influence of season. Most of the philopotamids were collected after mid-June and the simuliids were collected more often beginning in early to mid-June, peaking in July and declining in numbers towards mid-August. This suggests that there may have been some temporal variation in these collections due to the insects' life cycles. Repeated sampling over time at the same site would be required to confirm seasonal patterns.

The absence of any significant correlation between water temperature and either sampling date or the time of water temperature measurement lends support to the use of the single-point-in-time water temperature measurements for comparisons across sites. Hardness, alkalinity, and concentrations of calcium and dissolved inorganic carbon were inversely correlated with water temperature (Table 4). Cold water and elevated concentrations of these chemical variables indicate proximity to springs. Downstream from spring sources, water temperatures increase and, in addition, chemical changes occur due to the losses of carbon dioxide to the atmosphere and to photosynthesis which increase pH and cause the precipitation from solution of calcium carbonate (Hynes 1970; Ruttner 1963). Dissolved organic carbon and total Kjeldahl nitrogen were directly correlated with water temperature, perhaps indicative of increased input and in-stream generation of organic matter with increasing distance from spring sources (Meyer and Tate 1983). The relatively broad ranges of water temperature and correlated chemical concentrations across sites (Table 2) suggest differing degrees of influence from springs. Interestingly, there was no corresponding correlation between the above variables and distance from stream source as determined from 1:50 000 topographic maps. This suggests that, for these low-order streams, map distance may be a poor estimator of true proximity to spring sources. Concentrations of sulphate and dissolved inorganic carbon declined significantly over the sampling period, perhaps due to a seasonal increase in stream metabolism (Wetzel 1983).

Total taxon richness was directly correlated with water temperature and total Kjeldahl nitrogen, and inversely correlated with dissolved inorganic carbon. Again, this may reflect proximity to springs, as low species diversity is characteristic of some cold headwater streams (Vannote et al. 1980). However, the direct correlation between total taxon richness and

TABLE 4. Noteworthy significant correlations ($r \geq 0.374$, $p < 0.05$) between log(x + 1) transformed variables across sites on the Oak Ridges Moraine. (Abbreviations: DO – dissolved oxygen; Ca - calcium; DIC dissolved inorganic carbon; DOC – dissolved organic carbon; TKN – total Kjeldahl nitrogen; SO4 sulphate; PO4 – filtered reactive phosphate; NH3 – ammonia nitrogen).

Variable	Significantly correlated variables
Water temperature	DO^{-1}, $hardness^{-1}$, $alkalinity^{-1}$, Ca^{-1}, DIC^{-1}, DOC, TKN, total taxon richness
Sampling date	$conductivity^{-1}$, $SO4^{-1}$, DIC^{-1}, total taxon richness
Total taxon richness	water temperature, TKN, DIC^{-1}, sampling date
EPT taxon richness	pH, PO4, DOC^{-1}, $NH3^{-1}$

sampling date reinforces seasonal variation as a potential confounding variable. EPT taxon richness was directly correlated with pH and filtered reactive phosphate, and inversely correlated with dissolved organic carbon and ammonia nitrogen. The correlations with filtered reactive phosphate and ammonia nitrogen should be interpreted with caution because of the large number of observations that were less than the laboratory detection limits. There was no significant correlation between EPT taxon richness and water temperature, sampling date, or total taxon richness.

The model Oak Ridges Moraine community based on our study is shown in Table 5, compared with the New York State model for near-pristine streams. Mean percent affinity of the reference sites to the model was 67% for the Oak Ridges Moraine sites (range 32 - 80%, coefficient of variation = 15%) as compared to 81% for the New York State sites (range 72 - 86%, coefficient of variation = 5%). In contrast to the New York State model, oligochaetes were not important in the Oak Ridges Moraine model. Trichoptera and Plecoptera were more important, Ephemeroptera less so, although the total EPT contribution was the same (55%) in both models. Differences between the two models may reflect variations due to region, stream order, season, sampling techniques, samplers (Hannaford and Resh 1995), or may reflect the difficulty of locating truly pristine reference sites (Hughes 1995).

Novak and Bode (1992) used percent affinity to the model to assess the status of streams according to four categories of impairment. Shifts in dominance in the macroinvertebrate community from less tolerant groups to more tolerant groups cause a decrease in percent affinity to the model and suggest impaired conditions at a site. Novak and Bode (1992) caution, however, that the reasons for deviation from the model need to be understood; high contributions by an intolerant group may also result in low percent affinity and spuriously suggest impaired conditions. Low species diversity is characteristic of some cold headwater streams (Vannote et al. 1980), as well as polluted streams. Therefore, if one looks at species diversity, pristine and polluted streams may superficially resemble one another (Hilsenhoff 1977). Examples of this are seen in our data. Site 4 and site 29 had low percent affinities to the Oak Ridges Moraine model, the communities at these sites being over-represented by Ephemeroptera and Plecoptera respectively. At these sites the water was very cold and of all sites these had the lowest numbers of taxa. Based on the biotic index scores, however, the water quality at these two sites was excellent. Sampling of Oak Ridges Moraine sites along a gradient of disturbance would be required to refine the reference model, and to formulate proposed impact categories and associated percent affinity scores. The effect of increasing taxonomic resolution could also be explored. Barton (1996) used a percent model affini-

TABLE 5. Comparison of Oak Ridges Moraine (ORM) and New York State (NYS) models of benthic macroinvertebrate community structure. Shown is the mean percent contribution (%) of each invertebrate group to total abundance.

Group	ORM model		NYS model	
	%	(range)	%	(range)
Chironomidae	15	(0 - 50)	20	(8 - 34)
Trichoptera	25	(4 - 43)	10	(1 - 25)
Ephemeroptera	20	(0 - 88)	40	(21 - 60)
Plecoptera	10	(0 - 46)	5	(0 - 13)
Coleoptera	10	(0 - 38)	10	(1 - 22)
Oligochaeta	0	(0 - 7)	5	(0 - 19)
Other	20	(4 - 57)	10	(1 - 13)

ty approach to assess the relative impact of agriculture on benthic macroinvertebrate communities in southwestern Ontario. He found that the ability to discriminate between agricultural sites and reference sites was increased by increasing taxonomic resolution from the ordinal to the generic level. Most of the increase in discrimination was due to chironomids, which in the present study were identified only to the level of sub-family or tribe. For the time being, the Oak Ridges Moraine model may prove useful as a quick reference tool for the initial screening of sites, given that the requisite community composition information can be determined readily, in most cases even in the field.

Based on our study we conclude that undisturbed reference sites: (1) exhibit water quality that is typically better than applicable water quality standards, and (2) support diverse assemblages of benthic macroinvertebrates that include many taxa considered intolerant of pollution. This characterization of regional reference conditions provides a context for evaluating information concerning headwater streams of the Oak Ridges Moraine.

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Literature Cited

Barton, D. R. 1996. The use of percent model affinity to assess the effects of agriculture on benthic invertebrate communities in headwater streams of southern Ontario, Canada. Freshwater Biology 36: 397–410.

Bode, R. W. 1988. Quality assurance workplan for biological stream monitoring in New York State. New York State Department of Environmental Conservation, Albany, New York.

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. Water Quality Branch, Environment Canada, Ottawa, Ontario.

Chapman, L. J., and **D. F. Putman.** 1984. The physiography of southern Ontario. 3rd edition. Ontario Geological Survey, Special Volume 2.

Gallant, A. L., T. R. Whittier, D. P. Larsen, J. M. Omernik, and **R. M. Hughes.** 1989. Regionalization as a tool for managing environmental resources. EPA/600/3-89/060. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon.

Gerritsen, J. 1995. Additive biological indices for resource management. Journal of the North American Benthological Society 14: 451–457.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York.

Hannaford, M. J., and **V. H. Resh.** 1995. Variability in macroinvertebrate rapid-bioassessment surveys and habitat assessments in a northern California stream. Journal of the North American Benthological Society 14: 430–439.

Hilsenhoff, W. L. 1977. Use of arthropods to evaluate water quality of streams. Technical Bulletin Number 100, Department of Natural Resources, Madison, Wisconsin.

Hilsenhoff, W. L. 1982. Using a biotic index to evaluate water quality in streams. Technical Bulletin Number 132, Department of Natural Resources, Madison, Wisconsin.

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20: 31–39.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society 7: 65–68.

Hughes, R. M. 1995. Defining acceptable biological status by comparing with reference conditions. Pages 31–47 *in* Biological assessment and criteria: tools for water resource planning and decision making. *Edited by* W. S. Davis and T. P Simon. Lewis Publishers, Boca Raton, Florida.

Hughes, R. M., S. A. Heiskary, W. J. Matthews, and **C. O. Yoder.** 1994. Use of ecoregions in biological monitoring. Pages 125–151 *in* Biological monitoring of aquatic systems. *Edited by* S. L. Loeb and A. Spacie. Lewis Publishers, Boca Raton, Florida.

Hughes, R. M., D. P. Larsen, and **J. M. Omernik.** 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management 10: 629–635.

Hynes, H. B. N. 1970. The ecology of running waters. Liverpool University Press, Liverpool.

Intera Kenting. 1990. The hydrogeological significance of the Oak Ridges Moraine. Background paper prepared for The Greater Toronto Area Greenlands Strategy, Toronto, Ontario. ISBN 0-7729-7392-X.

Merritt, R. W., and **K. W. Cummins.** *Editors*. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Meyer, J. L., and **C. M. Tate.** 1983. The effects of watershed disturbance on dissolved organic carbon dynamics of a stream. Ecology 64: 33–44.

MNR [Ministry of Natural Resources], Ministry of the Environment, and Ministry of Municipal Affairs. 1991. Implementation guidelines - provincial interest on the Oak Ridges Moraine Area of the Greater Toronto Area. Toronto, Ontario.

MOE [Ministry of the Environment]. 1983. Handbook of analytical methods for environmental samples. Laboratory Services Branch, Toronto, Ontario.

MOEE [Ministry of Environment and Energy]. 1994. Water management policies, guidelines, provincial water quality objectives of the Ministry of Environment and Energy. Program Development Branch, Toronto, Ontario. ISBN 0-7778-3494-4.

Novak, M. A., and **R. W. Bode.** 1992. Percent model affinity: a new measure of macroinvertebrate community composition. Journal of the North American Benthological Society 11: 80–85.

ORMTWC [Oak Ridges Moraine Technical Working Committee]. 1994. The Oak Ridges Moraine Area strategy for the Greater Toronto Area: an ecological approach to the protection and management of the Oak Ridges Moraine. Toronto, Ontario.

Peckarsky, B. L., P. R. Fraissinet, M. A. Penton, and **D. J. Conklin, Jr.** 1990. Freshwater macroinvertebrates of northeastern North America. Cornell University Press, New York.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States. 2nd edition. John Wiley and Sons, New York.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and **R. M. Hughes.** 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA/444/4-89-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

RCFTW [Royal Commission on the Future of the Toronto Waterfront]. 1990. Watershed: interim report. Toronto, Ontario. ISBN 0-662-18012-7.

Resh, V. H., and **J. K. Jackson.** 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. Pages 195–233 *in* Freshwater biomonitoring and benthic macroinvertebrates. *Edited by* D. M. Rosenberg and V. H. Resh. Chapman and Hall, New York.

Ruttner, F. 1963. Fundamentals of limnology. 3rd edition, University of Toronto Press, Toronto.

Sokal, R. R., and **F. J. Rohlf.** 1969. Biometry. W. H. Freeman and Company, San Francisco.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and **C. E. Cushing.** 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science 37: 130–137.

Wetzel, R. G. 1983. Limnology. 2nd edition, Saunders College Publishing, Philadelphia.

Whittier, T. R., R. M. Hughes, and **D. P. Larsen.** 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Science 45: 1264–1278.

Williams, D. D., N. E. Williams, and **Y. Cao.** 1997. Spatial differences in macroinvertebrate community structure in springs in southeastern Ontario in relation to their chemical and physical environments. Canadian Journal of Zoology 75: 1404–1414.

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Breeding Bird Species Richness Associated with a Powerline Right-of-Way in a Northern Mixed Forest Landscape

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Transmission powerline rights-of-way potentially represent a cause of fragmentation and loss of forest habitat. We hypothesized that rights-of-way and associated edge effect could increase local bird species richness in a forested landscape. To address this question, we determined breeding bird species richness and abundance in forest, right-of-way, and forest edge in a mixed forest landscape in central Québec. Mean breeding bird species richness, cumulative richness, and Hurlbert richness index were higher in the forest and the edge than in the right-of-way. There was no significant difference between forest and edge. Cumulative richness in the edge was almost three times greater than in the right-of-way. No significant difference in abundance was observed between the edge and the forest for all bird species. Ten bird species in the forest and nine in the edge were more abundant than in the right-of-way. Three species were more abundant in the right-of-way than in the edge and the forest. The Chestnut-sided Warbler (*Dendroica pensylvanica*) was found only in the edge. Negative edge effect was limited at most to the Black-and-white Warbler (*Mniotilta varia*). The forest habitat provided most of the species richness observed; the right-of-way added a few species, while the edge added only one, the Chestnut-sided Warbler.

Les emprises de lignes de transport d'énergie représentent, potentiellement, une source de fragmentation et de perte d'habitat forestier. Nous avons proposé comme hypothèse que les emprises et l'effet de lisière associé peuvent accroître la richesse spécifique locale des oiseaux dans un paysage forestier. Pour la vérifier, nous avons déterminé la richesse spécifique et l'abondance des oiseaux nicheurs dans une emprise, dans la lisière de la forêt et en forêt, dans un paysage forestier de la forêt mixte, dans le centre du Québec. La richesse spécifique moyenne, la richesse cumulée et l'indice de richesse de Hurlbert des oiseaux nicheurs étaient plus élevés en forêt et en lisière que dans l'emprise. Il n'y avait aucune différence significative entre la forêt et la lisière. La richesse cumulative en lisière était trois fois plus élevée que dans l'emprise. Il n'y avait pas de différence significative d'abondance entre la lisière et la forêt pour toutes les espèces d'oiseaux. Dix espèces d'oiseaux dans la forêt et neuf en lisière étaient plus abondantes que dans l'emprise. Trois espèces étaient plus abondantes dans l'emprise que dans la forêt et la lisière. La Paruline à flancs marron (*Dendroica pensylvanica*) se trouvait seulement en lisière. L'effet négatif de lisière était limité, au plus, à la Paruline noir et blanc (*Mniotilta varia*). La forêt contribuait à presque toute la richesse spécifique observée: l'emprise ajoutait quelques espèces et la lisière en ajoutait une, la Paruline à flancs marron.

Key Words: breeding bird, species richness, edge effect, mixed forest, powerline right-of-way, forest fragmentation, Québec.

Odum (1983) defined "edge effect" as the tendency for increased variety and population density of organisms at community junctions. The transition zone between communities, known as the ecotone, commonly contains species of each communitiy. Furthermore, some species are characteristic of, and sometimes restricted to the ecotone (Odum 1983). Despite the fact that the concept remains somewhat simplistic, edge has long been considered beneficial for some forms of wildlife. Several empirical bird studies concerning the field-forest edge support the concept (Johnston 1947; Anderson et al. 1977; Strelke and Dickson 1980), but overall, studies remain inconclusive (Kroodsma 1984a, 1987). Alternative explanations for the observed edge effect include the natural territorial boundaries of forest bird species at the edge and singing post availability preferences of males in the open habitat (Anderson et al. 1977; Kroodsma 1984b). Nevertheless, some bird species have shown higher densities along the forest edge than in the forest interior (Whitcomb et al. 1981; Kroodsma 1982, 1984a; Freemark and Collins 1992).

In the early 1980s a new concept of edge effect began to emerge, where edges were altering biotic interactions. Several studies in North America reported higher rates of predation by various species and parasitism by Brown-headed Cowbird (*Molothrus ater*) along field-forest edges than in either habitat types (Gates and Gysel 1978; Wilcove 1985; see Paton 1994 for a review). Gates and Gysel (1978) suggested that such abrupt habitat discontinuities function as "ecological traps". Edge effect seems associated with forest fragmentation (Small and Hunter 1988; Paton 1994), and nesting success is associated with patch size (Wilcove 1985; Small and Hunter 1988; see Paton 1994 for a review). The relation between higher predation rate near the edge and patch size remains unclear (Small and Hunter 1988; Paton 1994) and edge effect might be affected by landscape. Kendeigh (1944) suspected a relation between the size of a forest tract and edge effect. Recent studies suggest that the number of area-sensitive bird species and forest-interior species in forest fragments is influenced by the landscape context (Freemark and Collins 1992; Friesen et al. 1995). How this applies to edge birds and edge effect is not clear, and quantitative empirical field data are necessary to address this question.

The present paper investigates the effects of a powerline right-of-way on the species richness of breeding birds in a mixed-forest landscape. We hypothesized that rights-of-way and associated edge could increase bird species richness in such a landscape. Specifically, we examined the contribution of the right-of-way, the forest, and the edge between these habitats to the overall species richness of breeding birds.

Study Area

The study area is located near Baie St-Paul, Québec, (47° 27' N, 70° 30' W), approximately 85 km northeast of Québec City. The underlying geological deposits are mainly Grenville granites, with sparse Ordovician rock outcrops of the St-Lawrence lowlands. Surface deposits are mainly heterogeneous till. The study site is located on a plateau with undulating hills, about 525-m above sea level. The regional landscape is mostly dominated by a Balsam Fir (*Abies balsamea*) and White Birch (*Betula papyrifera*) mixed forest, with some interspersed agricultural fields and clear-cuts more than 10 years old.

The 225 m wide right-of-way studied was east-west oriented. Three 735 kV powerlines, respectively built in 1965, 1966 and 1973, were located in the corridor. Prior to 1988, herbicides were used to control the vegetation in the right-of-way; since 1988, only mechanical methods have been used. The right-of-way vegetation was largely dominated by a shrub and tall-herb community. The dominant plant species include Blue-joint (*Calamagrostis canadensis*), Bracken (*Pteridium aquilinum*), and Large-leaved Aster (*Aster macrophyllus*). The right-of-way also included narrow forested buffer zones, dominated by willows (*Salix* spp.) and alders (*Alnus* spp.) along stream crossings (Deshaye et al. 1996).

Methods

The sampling unit for bird counts was a 1-ha plot (100 m × 100 m). The square shape was used to adjust to the right-of-way configuration and edge. The study area was divided in three sub-populations or strata (Cochran 1977): (1) the right-of-way stratum is made up of a 100 m wide band (99 m in the cleared right-of-way and 1 m in the adjacent forest), on both sides of the right-of-way; (2) the "edge", extending from 1 m to 101 m in the adjacent forest; and (3) the 100 m wide forest strip, 301 to 401 m from the right-of-way and at least 300 m from any forest gap or open habitat visible on aerial photographs (scale = 1:15 000). The 1 m strip of forest included in the right-of-way stratum allows for singing posts of species using the open habitat (Anderson et al. 1977); it also enables the observer to distinguish such species from those of the forest habitat. By locating the forest stratum 301 m from the limit of the right-of-way, we can assume no edge effect induced by the right-of-way in the forest stratum (Kroodsma 1987).

In each stratum, a total of 15 sampling plots were established for a total of 45. Sampling plots were randomly drawn in sets of three (right-of-way, edge, and forest). These sets were located 100 m apart along the right-of-way, and alternating from one side of the right-of-way to the other, according to a systematic sampling design (Cochran 1977). This spacing was used to achieve independence between sampling plots within a given stratum. A preliminary field visit indicated recent cuts in the forest at the study site. Some paired plots had to be moved to circumvent that problem. The plots were spread along 3.2 km of powerline right-of-way. Field constraints mainly related to many rainy days, accompanied by high voltage conductor noise, made it impossible to census each plot three times during the field period allocated for the study. Eight of the 35 plots were visited only twice. In most cases, the evening visit was cancelled. Because the evening visit yielded relatively few bird observations, we consider that inter-strata comparisons are still valid. Detailed vegetation description was not achieved in four plots also due to time constraints.

Bird counts

Each plot was predetermined by marking its central axis with flagging tape perpendicular to the right-of-way. On each visit, after a pause of 3 to 5 minutes following the arrival of the observer at the count site, all birds seen or heard in the 1-ha plot within a 20-minute period were recorded (Blondel et al. 1981). Bird counts were done from the center of the plot; however, at times the observer moved carefully to determine if a singing male was within the plot. The same observer conducted three bird counts on each plot on different days, two in the morning and one at the end of the day. The two morning counts were spaced by at least one week. In the morning, bird counts began at sunrise and generally ended before 09:00 (04:35-10:40). In each plot, at

TABLE 1. Habitat variables used to described sample plots in forest, edge and right-of-way.

Habitat variable	Description
Conifers	Percentage of conifer cover
Snags	Class abundance of snags (d.b.h. ≥ 10 cm)[a]
Forest gaps	Number of forest gaps (≥ 5 m of diameter)
Fallen Logs	Abundance class of fallen trees[a]
Moss	Moss cover (11 classes of abundance)[b]
Short herbs	Percentage cover of short herbs (< 0.3 m; 11 classes)[b]
Tall herbs	Percentage cover of tall herbs (≥ 0.3 m; 11 classes)[b]
Low shrub	Low shrub cover (< 2 m; 11 classes of abundance)[b]
Tall shrub	Tall shrub cover (≥ 2 m; 11 classes of abundance)[b]
Lower canopy	Cover of lower canopy (5–10 m; 11 classes of abundance)[b]
Mid canopy	Cover of mid canopy trees (10–20 m; 11 classes of abundance)[b]
High canopy	Cover of high canopy trees (> 20 m; 11 classes of abundance)[b]
Slope	Slope (degree)
Drainage	Drainage index[c]
Insect abundance	Visual evaluation of insects and defoliation of conifers[d]

[a]Classes: 0: 0; 1: 1–10; 2: 11–20; 3: 21–30; etc.
[b]Classes: 0: 0; 1: 1–10 %; 2: 11–20 %; .... 11: 91–100 %.
[c]Classes: 1: wet, 2: humid, 3: mesic and 4: xeric.
[d]Classes: 0: none, 1: low, 2: medium, and 3: high.

least one of the morning counts started before 07:30. At the end of the day, counts usually started after 16:30 and were terminated prior to sunset (15:45-19:55). Counts were made on rainless days, with little or no wind. All count sessions were made between 8 and 25 June 1996. We assumed that the number of birds recorded was related to bird density (Raphael 1987) and that bird detectability was similar between strata.

We measured a number of habitat characteristics on each sample plot to determine if a difference in species relative abundance between edge and forest interior was due to edge effect rather than to forest structure. Fifteen variables were used to determine overall plot characteristics (Table 1). For each plot and bird species, the highest abundance recorded during one of the three count sessions was used for statistical analyses. Bird species richness was estimated using three formulas: cumulative richness, Hurlbert richness index (Hurlbert 1971) and mean richness. Cumulative richness refers to the number of species observed in all the plots of a sample. Because estimated cumulative richness is a function of sample size, Hurlbert richness index was used to compare unequal-size samples. This estimator gives the mathematical expectancy of the number of

TABLE 2. Habitat variables for right-of-way, edge and forest strata. Variables from three groups were compared using the Kruskal-Wallis (K-W) and Wilcoxon tests (ROW = right-of-way).

Variable name	Stratum (Mean ± SD) ROW (n = 13)	Edge (n = 13)	Forest (n = 5)	K-W test P	Wilcoxon test ($P < 0.05$)
Conifers	–	13.6 ± 18.0	7.0 ± 10.1	–	0.18
Snags	0.0 ± 0.0	2.4 ± 1.4	2.6 ± 1.1	–	0.53
Forest gaps	–	1.8 ± 1.2	2.8 ± 1.5	–	0.24
Fallen logs	0.0 ± 0.0	1.6 ± 1.4	1.4 ± 0.9	–	0.79
Moss	5.0 ± 3.5	1.2 ± 0.4	1.4 ± 0.9	0.0017	ROW > (Forest, edge)
Short herbs	3.7 ± 1.3	1.3 ± 0.5	1.8 ± 0.4	0.0001	ROW> (Forest, edge)
Tall herbs	3.7 ± 2.1	1.1 ± 0.3	1.2 ± 0.4	0.0001	ROW> (Forest, edge)
Low shrub	2.8 ± 0.7	2.2 ± 0.8	2.2 ± 0.4	0.1341	–
Tall shrub	0.6 ± 0.5	2.9 ± 1.3	3.6 ± 0.9	0.0001	(Forest, edge) > ROW
Lower canopy	0.0 ± 0.0	4.0 ± 1.6	4.4 ± 1.7	–	0.73
Mid canopy	0.0 ± 0.0	3.9 ± 2.3	2.8 ± 1.5	–	0.42
High canopy	0.0 ± 0.0	0.8 ± 0.4	0.6 ± 0.9	–	0.46
Slope	8.8 ± 4.8	12.9 ± 7.4	11.4 ± 4.8	0.2818	–
Drainage	2.3 ± 0.7	2.3 ± 0.5	2.6 ± 0.5	0.5589	–
Insect abundance	–	0.0 ± 0.0	0.0 ± 0.0	–	–

TABLE 3. Breeding bird species richness comparison between right-of-way, edge and forest strata.

Stratum	Number of plots	Mean richness (SD)	Cumulative richness	Hurlbert richness index
Right-of-way	14	5.1 (1.7)	15	11
Edge	14	10.3 (1.6)	41	31
Forest	7	9.3 (1.0)	27	27

species represented in samples which sizes are reduced to that of the smallest sample being compared. The mean richness is the average number of bird species observed per plot in a stratum.

Habitat variables, mean richness and relative bird density for the three strata were compared using the Kruskal-Wallis test. When a distribution heterogeneity was detected, the Wilcoxon test was used to identify which stratum differed from another.

Results

Habitat variables

No habitat variables were significantly different between edge and forest, but there was a tendency for short herbs cover to be greater in forest plots (Table 2; $P = 0.076$). In many edge and forest plots there were some small gaps in the forest canopy due to windfall, rock outcrops and past Spruce Budworm (*Choristoneura fumiferana*) outbreaks.

The right-of-way habitat was quite different from either forest or edge habitat mainly because of the absence of canopy. Mosses, short and tall herbs cover was significantly greater in the right-of-way than in the other two groups. Tall shrub cover was significantly less in the right-of-way than in the edge and the forest strata (Table 2).

Bird species richness

A total of 47 bird species was recorded in the sampling plots during the count sessions. Results show heterogeneity in mean richness between strata (Table 3; Kruskal-Wallis test; 2 d.f.; $P = 0.0001$). Mean species richness was greater in the forest and in the edge than in the right-of-way (Wilcoxon test; 1 d.f.; $P = 0.0004$ and 0.0001 respectively). There was no significant difference between forest and edge ($P = 0.07$).

Cumulative richness in the edge was almost three times greater than in the right-of-way (Table 3; equal sample size). It was also greater in the forest than in the right-of-way despite a smaller sample size in the forest (Table 3). Cumulative richness was greater in the edge than in the forest, but Hurlbert richness index indicated that the difference was probably due in a large part to the smaller sample size for the forest.

Relative abundance

Warblers made up about half of the bird abundance in the edge and in the forest, and respectively 34.1 % and 40.7 % of the cumulative richness. There was no significant difference in abundance between edge and forest for all bird species (Table 4). However, the Chestnut-sided Warbler (*Dendroica pensylvanica*) was observed in five edge plots but not in the forest. All the Chestnut-sided Warbler activity was compressed along the edge and right-of-way interface. Black-and-white Warbler (*Mniotilta varia*) abundance showed a tendency to be greater in the forest than in edge ($P = 0.09$).

Ten species were significantly more abundant in the forest than in the right-of-way (Table 4). Nine were also significantly more abundant in the edge than in the right-of-way. These species were found only in the forest and in the edge, except for the Red-eyed Vireo (*Vireo olivaceus*). American Robin (*Turdus migratorius*) and White-throated Sparrow (*Zonotrichia albicollis*) which were found in all three strata.

In the right-of-way, four species dominated the bird community: Alder Flycatcher (*Empidonax alnorum*), Common Yellowthroat (*Geothlypis trichas*), Lincoln's Sparrow (*Melospiza lincolnii*) and White-throated Sparrow (Table 4). The first three species were significantly more abundant in the right-of-way than in the forest and in the edge. They were also restricted to the right-of-way, as with the Mourning Warbler (*Oporornis philadelphia*) and the Song Sparrow (*Melospiza melodia*). Sparrows comprised nearly 40 % of the right-of-way bird community. The Nashville Warbler (*Vermivora ruficapilla*) and the Magnolia Warbler (*Dendroica magnolia*) activity was compressed along the right-of-way and edge margin. No Brown-headed Cowbirds were observed in the study area.

Discussion

The lack of significant differences in habitat variables measured between edge and forest indicated that a difference in bird species richness could be attributable to edge effect. We found no evidence that cumulative species richness was greater near the edge than in the forest. We suspect that fewer plots in the forest could explain part of that difference, as indicated by the Hurlbert richness index. These results are somewhat inconsistent with those of previous studies that reported more passerine species at the forest edge than in the interior (Anderson et al.

TABLE 4. Comparison of abundance (mean number of pairs/sampling plot) of bird species between strata (mean ± standard error; means underlined differ significantly from those not underlined [Wilcoxon test, $P < 0.05$]).

Bird species	Right-of-way	Edge	Forest
Broad-winged Hawk (*Buteo platypterus*)	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0
Ruffed Grouse (*Bonasa umbellus*)	0.0 ± 0.0	+[a]	0.0 ± 0.0
Ruby-throated Hummingbird (*Archilochus colubris*)	0.0 ± 0.0	+	0.0 ± 0.0
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	0.0 ± 0.0	0.2 ± 0.4	0.1 ± 0.2
Downy Woodpecker (*Picoides pubescens*)	0.0 ± 0.0	0.1 ± 0.2	0.0 ± 0.0
Hairy Woodpecker (*Picoides villosus*)	+	0.1 ± 0.2	0.0 ± 0.0
Northern Flicker (*Colaptes auratus*)	0.1 ± 0.3	0.1 ± 0.4	0.0 ± 0.0
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.4
Alder Flycatcher (*Empidonax alnorum*)	1.2 ± 0.7	0.0 ± 0.0	0.0 ± 0.0
Least Flycatcher (*Empidonax minimus*)	0.0 ± 0.0	0.1 ± 0.4	0.0 ± 0.0
Solitary Vireo (*Vireo solitarius*)	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0
Red-eyed Vireo (*Vireo olivaceus*)	0.1 ± 0.3	0.8 ± 0.7	0.8 ± 0.7
Blue Jay (*Cyanocitta cristata*)	0.0 ± 0.0	0.1 ± 0.2	0.1 ± 0.2
Common Raven (*Corvus corax*)	0.0 ± 0.0	0.1 ± 0.5	0.0 ± 0.0
Black-capped Chickadee (*Poecile atricapillus*)	0.0 ± 0.0	0.4 ± 0.5	0.3 ± 0.5
Red-breasted Nuthatch (*Sitta canadensis*)	0.0 ± 0.0	0.3 ± 0.3	0.2 ± 0.4
Winter Wren (*Troglodytes troglodytes*)	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.4
Golden-crowned Kinglet (*Regulus satrapa*)	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.4
Ruby-crowned Kinglet (*Regulus calendula*)	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.4
Veery (*Catharus fuscescens*)	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.2
Swainson's Thrush (*Catharus ustulatus*)	0.0 ± 0.0	0.7 ± 0.6	0.6 ± 0.4
Hermit Thrush (*Catharus guttatus*)	0.0 ± 0.0	0.2 ± 0.4	0.1 ± 0.4
American Robin (*Turdus migratorius*)	0.2 ± 0.3	0.6 ± 0.6	0.3 ± 0.4
Cedar Waxwing (*Bombycilla cedrorum*)	0.1 ± 0.2	0.1 ± 0.4	0.2 ± 0.4
Tennessee Warbler (*Vermivora peregrina*)	0.1 ± 0.3	0.1 ± 0.3	0.0 ± 0.0
Nashville Warbler (*Vermivora ruficapilla*)	0.2 ± 0.4	0.5 ± 0.6	0.7 ± 0.8
Northern Parula (*Parula americana*)	0.0 ± 0.0	0.1 ± 0.3	0.1 ± 0.4
Chestnut-sided Warbler (*Dendroica pensylvanica*)	0.4 ± 0.5	0.4 ± 0.5	0.0 ± 0.0
Magnolia Warbler (*Dendroica magnolia*)	0.1 ± 0.3	0.3 ± 0.5	0.6 ± 0.8
Black-throated Blue Warbler (*Dendroica caerulescens*)	0.0 ± 0.0	0.4 ± 0.5	0.4 ± 0.5
Yellow-rumped Warbler (*Dendroica coronata*)	0.0 ± 0.0	0.2 ± 0.4	0.1 ± 0.4
Black-throated Green Warbler (*Dendroica virens*)	0.0 ± 0.0	0.5 ± 0.5	0.4 ± 0.8
Blackburnian Warbler (*Dendroica fusca*)	0.0 ± 0.0	0.6 ± 0.6	0.4 ± 0.5
Bay-breasted Warbler (*Dendroica castanea*)	0.0 ± 0.0	0.3 ± 0.5	0.4 ± 0.5
Black-and-white Warbler (*Mniotilta varia*)	0.0 ± 0.0	0.1 ± 0.4	0.4 ± 0.5
American Redstart (*Setophaga ruticilla*)	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0
Ovenbird (*Seiurus aurocapillus*)	0.0 ± 0.0	0.7 ± 0.6	1.0 ± 0.6
Mourning Warbler (*Oporornis philadelphia*)	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
Common Yellowthroat (*Geothlypis trichas*)	1.1 ± 0.8	0.0 ± 0.0	0.0 ± 0.0
Canada Warbler (*Wilsonia canadensis*)	0.0 ± 0.0	0.2 ± 0.4	0.3 ± 0.5
Song Sparrow (*Melospiza melodia*)	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
Lincoln's Sparrow (*Melospiza lincolnii*)	1.0 ± 0.5	0.0 ± 0.0	0.0 ± 0.0
White-throated Sparrow (*Zonotrichia albicollis*)	1.1 ± 0.8	0.7 ± 0.6	0.6 ± 0.5
Dark-eyed Junco (*Junco hyemalis*)	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.0
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	0.0 ± 0.0	0.1 ± 0.4	0.1 ± 0.4
Purple Finch (*Carpodacus purpureus*)	0.0 ± 0.0	0.1 ± 0.4	0.0 ± 0.0
White-winged Crossbill (*Loxia leucoptera*)	0.0 ± 0.0	+	0.0 ± 0.0

[a]Present.

1977; Small and Hunter 1989; Larue et al. 1995). In Maine, Small and Hunter (1989) found more passerine species in the forest within 30 m of a right-of-way than in a strip 60 to 90 m from the right-of-way. In contrast, Hanowski et al. (1995) found similar numbers of species in edge and forest. These investigators excluded the 25 m forest strip next to the right-of-way, and they suggested that the inconsistency could be attributed to difference in study design. In our study, the scale of observation was 100 m wide and this might have diluted an edge effect not exceeding 30 m from the interface. Furthermore, small gaps in the forest due to windfall, rock outcrops and Spruce Budworm outbreaks created some edge and could explain, in part, why American Robin, Cedar Waxwing (*Bombycilla cedrorum*), Nashville Warbler and White-throated Sparrow were not more abundant in the edge than in the forest interior in our study area. Freemark and Collins (1992) recognized these species as typical edge species. The Chestnut-sided Warbler was probably the exception: this species was limited to the edge, more precisely to the forest right-of-way interface as indicated by singing posts. This is consistent with the results of other investigators in Maine and Wisconsin (Small and Hunter 1989; Hanowski et al. 1995). This could be explained by the small size of the gaps in the forest or because these gaps are partly covered by Balsam Fir saplings, whereas within the right-of-way itself, deciduous saplings dominated patches adjacent to the right-of-way-forest interface.

In this study, the presence of the right-of-way did not seem to affect abundance of forest bird species, except perhaps Black-and-White Warbler. Other investigators have found bird species such as Ovenbird (*Seiurus aurocapillus*), Black-and-White Warbler, and Canada Warbler to be more abundant in forest interior than at the edge (Whitcomb et al. 1981; Kroodsma 1984a; Small and Hunter 1989; Larue et al. 1995). Hanowski et al. (1995) found that only Black-and-white Warbler was significantly more abundant in forest than in edge. They suggested that the differences in their results and those of other studies could be due to the amount and type of forest fragmentation in the landscape; many previous studies were conducted in highly fragmented forest settings whereas their study was conducted in a forested landscape. However, Larue et al. (1995) also conducted their study in a forested landscape. As a whole these results indicated that the negative edge effect does not depend solely on forest fragmentation. In our study, presence of small gaps in the forest could have minimized negative edge effect.

Breeding bird species richness in the right-of-way was much less than in the edge and forest. The cumulative richness in the edge was three times greater than in the right-of-way. The cumulative richness in the forest was also much greater than in the right-of-way. These results contrast with those of Bramble et al. (1984) who found more bird species in the right-of-way than in the forest. However, their right-of-way sampling unit enclosed a 10-m strip of forest.

In our study, most species which dominated the bird assemblage in the right-of-way (Alder Flycatcher, Common Yellowthroat and Lincoln's Sparrow) were not found in the forest. According to Anderson et al. (1977), wider corridors tend to contain a poorer bird community than that of the forest. That difference is smaller in the case of narrow corridors. This might explain the low number of species observed in the 225 m wide right-of-way sampled in the present study.

In the northern mixed forest landscape studied, the forest provided most of the bird species richness. Rights-of-way provide open habitat more permanent than that created by natural factors (e.g., fires), as a result of vegetation control activities in rights-of-way. The right-of-way added a few species to the overall richness, while edge possibly added only one, Chestnut-sided Warbler.

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Literature Cited

Anderson, S. H., K. Mann, and **H. H. Shugart, Jr.** 1977. The effect of transmission-line corridors on bird populations. American Midland Naturalist 97: 216–221.

Bibby, C. J., N. D. Burgess, and **D. A. Hill.** 1992. Bird census techniques. British Trust for Ornithology and Royal Society for the Protection of Birds, Academic Press, London.

Blondel, J., C. Ferry, and **B. Frochot.** 1981. Point counts with unlimited distance. Pages 414–420 *in* Estimating the numbers of terrestrial birds. *Edited by* C. J. Ralph and J. M. Scott. Studies in Avian Biology Number 6.

Bramble, W. C., W. R. Byrnes, and **M. D. Schuler.** 1984. The bird population of a transmission right-of-way maintained by herbicides. Journal of Arboriculture 10: 13–20.

Cochran, W. G. 1977. Sampling techniques. Wiley, New York.

Freemark, K., and **B. Collins.** 1992. Landscape ecology of birds breeding in temperate forest fragments. Pages 443–454 *in* Ecology and conservation of neotropical migrant landbirds. *Edited by* J. M. Hagan and D. W. Johnston, Smithsonian Institution Press, Washington, D.C.

Friesen, L. E., P. F. J. Eagles, and **R. J. MacKay.** 1995. Effects of residential development on forest-dwelling Neotropical migrant songbirds. Conservation Biology 9: 1408–1414.

Gates, J. E., and **L. W. Gysel.** 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology 59: 871–883.

Hanowski, J. M., G. J. Niemi, and **J. G. Blake.** 1995. Seasonal abundance and composition of forest bird communities adjacent to a right-of-way in northern forests USA. Pages 276–283 *in* Proceedings of the fifth International symposium on environmental concerns in rights-of-way management. *Edited by* G. J. Doucet, C. Séguin, and M. Giguère. Hydro-Québec, Montréal, Québec.

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52: 577–586.

Johnston, V. R. 1947. Breeding birds of the forest edge in Illinois. Condor 49: 45–53.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecological Monographs 14: 67–106.

Kroodsma, R. L. 1982. Edge effect on breeding forest birds along a power-line corridor. Journal of Applied Ecology 19: 361–370.

Kroodsma, R. L. 1984a. Effect of edge on breeding forest bird species. Wilson Bulletin 96: 426–436.

Kroodsma, R. L. 1984b. Ecological factors associated with degree of edge effect in breeding birds. Journal of Wildlife Management 48: 418–425.

Kroodsma, R. L. 1987. Edge effect on breeding birds along power-line corridors in East Tennessee. American Midland Naturalist 118: 275–283.

LaRue, P., L. Bélanger, and **J. Huot.** 1995. Riparian edge effects on boreal balsam fir bird communities. Canadian Journal of Forest Research 25: 555–566.

Odum, E. P. 1983. Basic Ecology. Philadelphia. Saunders.

Paton, P. W. C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology 8: 17–26.

Raphael, M. G. 1987. Estimating relative abundance of forest birds: simple versus adjusted counts. Condor 89: 127–136.

Small, M. F., and **M. L. Hunter.** 1988. Forest fragmentation and avian predation in forested landscapes. Oecologia 76: 62–64.

Small, M. F., and **M. L. Hunter.** 1989. Response of passerines to abrupt forest-river and forest-powerline edges in Maine. Wilson Bulletin 101: 77–83.

Strelke, W. K., and **J. G. Dickson.** 1980. Effect of forest clear-cut edge on breeding birds in east Texas. Journal of Wildlife Management 44: 559–567.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and **D. Bystrak.** 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125–205 *in* Forest island dynamics in man-dominated landscapes. *Edited by* R. L. Burgess and D. M. Sharpe, Springer-Verlag, New York, New York.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66: 1212–1214.

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Characteristics of Canada Lynx, *Lynx canadensis*, Maternal Dens and Denning Habitat

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Female Canada Lynx (*Lynx canadensis*) use maternal dens from birth until the kits are weaned and foraging with their mothers. I inspected 39 den sites during a long-term study of lynx population dynamics in southwestern Yukon. Most dens were under deadfall debris in burns, which predominated in the study area. Blowdown debris, mature and shrub subalpine fir trees, and willow shrub thickets were also used for denning in burned or unburned areas. Dens were generally located mid-slope and faced south or southwest. Dens were not re-used in subsequent years. Den sites of neighbouring females, and sites used by females in different years, were as close as 300 m. Females occasionally relocated dens even when not disturbed by the investigators. Den sites are an important habitat feature which, along with foraging habitat, cover and travel corridors, may enhance lynx recruitment. Den site availability should be taken into consideration when managing or assessing changes to lynx habitats.

Key Words: Canada Lynx, *Lynx canadensis*, habitat, maternal den, natal den, Yukon Territory.

Many factors likely effect the selection of habitat by Canada Lynx (*Lynx canadensis*). The abundance of Snowshoe Hares (*Lepus americanus*) or other prey, conditions that favour hunting success, and cover from predators (Murray et al. 1994). Other requirements include travel corridors that avoid open areas (Parker 1981; Murray et al. 1994; Poole et al. 1996) and habitat for maternal dens. Understanding the components of lynx habitat facilitates lynx habitat management (Washington State Department of Natural Resources 1996*) and the assessment of impacts of habitat modifications such as wildfire and forestry (Poole et al. 1996; Paragi et al. 1997).

There are few published descriptions of habitats at dens. In the boreal forest, early and mid-successional post-fire seres in burns 15 to 30 years old appear to provide optimal lynx and hare habitat, but lynx have been shown to use burns from 5 to 50 years old (Kesterson 1988; Thompson 1988; Staples 1995; Poole et al. 1996; Paragi et al. 1997). Mature forest stands may also be important for cover, socializing, as movement corridors and as a source of alternative prey when Snowshoe Hares are scarce (Saunders 1963; Parker 1981; Staples 1995; O'Donoghue et al. 1998). Lynx will use, but tend to avoid, open areas when hunting prey (Parker 1981; Murray et al. 1994; K. Poole, Northwest Territories Wildlife Management Division, unpublished data) and, conversely, very dense cover may be a disadvantage for lynx when hunting Snowshoe Hare (Major 1989; Murray et al. 1994). Coarse woody debris is an important structural component of den sites, whether in burns (K. Poole, Northwest Territories Wildlife Management Division, unpublished data; B. G. Slough and R. M. P. Ward, Yukon Fish and Wildlife Branch, unpublished data) or in mature forest stands (Brittell et al. 1989*; Koehler 1990).

The objectives of this study were to describe the characteristics of lynx den sites and the surrounding forest stands. I also recorded degree of den site fidelity by comparing distances between den sites of marked individuals among successive years, and distances between den sites of neighbouring females within years, and the age of kits using dens.

Study Area

Field studies were conducted on a 301 km^2 area located approximately 100 km southeast of Whitehorse, Yukon Territory (60°15′N, 135°20′W) (Slough and Mowat 1996). Weathered mountains dissected by creek valleys characterized the area. Elevations ranged from 800 to 1950 m. Seventy-two percent of the area was burned or partially burned in 1958. Regenerating shrubs and trees were predominantly Lodgepole Pine (*Pinus contorta*), White Spruce (*Picea glauca*), Trembling Aspen (*Populus tremuloides*), Subalpine Fir (*Abies lasiocarpa*), and Willows (*Salix* spp.). Standing dead trees were present in patches; however, most burned trees had fallen to create debris piles 1.5-m tall. Residual patches of mature timber covered 9% of the area, riparian willows 5%, and lakes 3%. Alpine tundra (11%) occurred at elevations above 1220 to 1400 m.

*See Documents Cited

Methods

Forty-five female lynx were fitted with collar-mounted radio transmitters during a study of lynx population dynamics (Slough and Mowat 1996). Den sites were located by radio-tracking females between May and July, 1987 to 1994, as described by Mowat et al. (1996). Birth dates were estimated from Jackson's (1987) body mass growth curves for Bobcats (*Felis rufus*) and from data for a captive lynx kit (4 weekly measurements from 21 to 42 days of age; J. L. Weaver, Northern Rockies Conservation Cooperative, Missoula, Montana, unpublished data).

The surrounding vegetation type, overhead cover, aspect and other characteristics of den sites were recorded when sites were visited. Den site locations were plotted on 1:50 000 scale topographic maps with 100-foot contour intervals. Elevations of dens were obtained from the topographic maps. Means are ± 1 standard deviation.

Results

Thirty-nine occupied den sites of 24 different females were inspected (Table 1). Due to the cyclic nature of both the lynx population and successful reproduction (Mowat et al. 1996; Slough and Mowat 1996), the greatest number of denning females occurred in 1990 and 1991 (n = 33). Lynx litters varied in age from < 1 day (i.e., newborn litter) to 33 days (18.7 ± 10.0 days). The mean date that females gave birth was May 23 ± 6 days for 29 adults and June 17 ± 7 days for 5 yearlings. Maternal den sites were used until the kits were about 6 to 8 weeks of age.

Thirty-five dens were located in burns; 33 of these were under the deadfall of fire-killed coniferous trees, usually in jackstrawed debris piles. One was a second den site chosen by the female after disturbance by researchers and was 300 m from the original site. In several cases (both before and after our visits) females relocated to new den sites. An unburned mature Subalpine Fir, a regenerating Subalpine Fir shrub, and unburned mature White Spruce provided additional overhead cover to deadfall in three cases. Of the remaining two dens located in burns, cover was provided by a mature Subalpine Fir tree and a Fir shrub in the absence of deadfall in both cases.

TABLE 1. Trees and shrubs characteristic of lynx maternal and denning habitat.

Stand Components[1]	Overhead Cover Components	Number of lynx dens
Burned		
Pine	Pine deadfall	12
Pine/spruce	Pine deadfall	4[2]
	Pine/spruce deadfall	1
	Spruce deadfall/mature spruce blowdown	1
Pine/fir	Pine deadfall	1
	Fir deadfall	1
	Pine/fir deadfall	2
	Mature fir	1
Pine/spruce/fir	Pine deadfall/fir shrub	1
	Spruce deadfall	1
	Fir shrub	1
Spruce	Spruce deadfall	4
Spruce/fir	Spruce deadfall	1
	Spruce/fir deadfall	1
	Fir deadfall	1
Fir	Fir deadfall	1
	Fir deadfall/mature fir	1
Unburned		
Mature spruce	Mature spruce blowdown	1
Mature fir	Mature fir tree	1
Mature spruce/fir	Willow thicket	1
Riparian willow	Willow thicket	1
Total		39

[1]Pine = *Pinus contorta*, Spruce = *Picea glauca*, Fir = *Abies lasiocarpa*, Willow = *Salix* spp.
[2]Includes a relocated den.

Four dens were located in unburned vegetation types; one was under mature Spruce blowdown, one was under a mature Fir tree, and two were under Willow thickets.

Trembling Aspen occurred in the study area, but both burned and unburned Aspen stands were open, and I did not observe the use of such stands for denning.

Dens were generally located mid-slope between 900 and 1390-m elevation (1120 ± 98 m), but not above tree line. Distribution of den site aspects was not uniform (χ^2 = 17.34, df = 7, P = 0.015). South (n = 9) and southwest (n = 9) aspects were chosen for almost half of the dens. Five dens were located on flat terrain.

Den sites of females with overlapping or adjacent home ranges were as close as 300 m apart, and in six other cases were within 2.5 km of each other. Individual females did not reuse den sites in subsequent years, but sites were often close to those previously used. Of eight females whose den site locations were monitored for two (n = 7) or four years (n = 1), six subsequent den sites were 300 to 900 m from previous sites, and four were 1.8 to 4.2 km from previous sites. Lynx did not appear to modify the den sites by pawing, although constant use compressed vegetative matter such as leaves and moss, forming a slight depression.

One known natal den (there was a stillborn kit present) and five others were visited within five days of birth. There was no noticeable difference between probable natal dens and maternal dens (dens used for rearing kits but not necessarily for parturition).

Discussion

The characteristics of lynx natal and maternal dens were synonymous; therefore maternal dens are defined to include natal dens. The common feature of lynx maternal den sites across its range is the preferred use of coarse woody debris such as downed logs from windthrow in mature forests (Brittell et al. 1989*; Koehler 1990; Koehler and Aubry 1994*), or deadfall within burns (K. G. Poole, Northwest Territories Wildlife Management Division, unpublished data; this study). Dense horizontal and vertical cover protects the litter from mammalian and avian predation, from wind and precipitation, and provides additional escape cover (Koehler 1990). The preference for south and southwest aspects in the Yukon, where temperatures are cooler in spring and summer, and north and northeast aspects in Washington (n = 4; Koehler 1990), where temperatures are warmer, indicates the importance of a moderate ambient temperature at the den site.

Relocation den sites may be common in natural situations (Washington Department of Natural Resources 1996*). The availability of alternative den sites connected by suitable travel corridors could be an important determinant of habitat quality (Koehler and Aubry 1994*). A lack of suitable den sites in an area could potentially reduce lynx recruitment. The high lynx densities (up to 44.9 lynx/100km^2) reported by Slough and Mowat (1996) may have been achieved in part due to the availability of denning habitat throughout individual lynx home ranges and the study area as a whole.

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Documents Cited

Brittell, J. D., R. J. Poelker, S. J. Sweeney, and **G. M. Koehler.** 1989. Native cats of Washington. Section III: Lynx. Washington Department of Wildlife, Olympia.

Koehler, G. M., and **K. B. Aubry.** 1994. Lynx. Pages 74–98 *in* The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. *Edited by* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. L. Jack, W. J. Zielinski, and J Williams. United States Department of Agriculture, Forest Service, Rocky Mountain Forest.

Washington State Department of Natural Resources. 1996. Lynx habitat management plan for DNR managed lands. Olympia.

Literature Cited

Jackson, D. L. M. 1987. Growth and development of captive bobcats (*Felis rufus*). M.Sc. thesis, Mississippi State University, Mississippi State.

Kesterson, M. D. 1988. Lynx home range and spatial organization in relation to population density and prey abundance. M.Sc. thesis, University of Alaska, Fairbanks.

Koehler, G. M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Canadian Journal of Zoology 65: 565–567.

Major, A. R. 1989. Lynx *Lynx canadensis canadensis* (Kerr) predation patterns and habitat use in the Yukon Territory, Canada. M.Sc. thesis, State University of New York, Syracuse.

Mowat, G., B. G. Slough, and **S. Boutin.** 1996. Lynx recruitment during a snowshoe hare decline in the southwest Yukon. Journal of Wildlife Management 60: 441–452.

Murray, D. L., S. Boutin, and **M. O'Donoghue.** 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. Canadian Journal of Zoology 72: 1444–1451.

O'Donoghue, M., S. Boutin, C. J. Krebs, D. L. Murray, and **E. J. Hofer.** 1998. Behavioural responses of coyotes and lynx to the snowshoe hare cycle. Oikos 82: 169–183.

Paragi, T. F., W. N. Johnson, and **D. D. Katnik.** 1997. Selection of post-fire seres by lynx and snowshoe hares in the Alaskan taiga. Northwestern Naturalist 78: 77–86.

Parker, G. R. 1981. Winter habitat use and hunting activities of lynx (*Lynx canadensis*) on Cape Breton Island, Nova Scotia. Pages 221–248 *in* Proceedings of the worldwide furbearer conference. *Edited by* J. A. Chapman and D. Pursley. Frostburg, Maryland.

Poole, K. G., L. A. Wakelyn, and **P. N. Nicklen.** 1996. Habitat selection by lynx in the Northwest T erritories. Canadian Journal of Zoology 74: 845–850.

Saunders, J. K. 1963. Movements and activities of the lynx in Newfoundland. Journal of Wildlife Management 27: 390–400.

Slough, B. G., and **G. Mowat.** 1996. Lynx population dynamics in an untrapped refugium. Journal of Wildlife Management 60: 946–961.

Staples, W. R., III. 1995. Lynx and coyote diet and habitat relationships during a low hare population on the Kenai National Wildlife Refuge, Alaska. M.Sc. thesis, University of Alaska, Fairbanks.

Thompson, I. D. 1988. Habitat needs of furbearers in relation to logging in boreal Ontario. Forestry Chronicle 65: 251–261.

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Effets du nourrissage artificiel sur les déplacements hivernaux de Cerfs de Virginie, *Odocoileus virginianus*, vivant au nord de leur aire de répartition

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Le nourrissage artificiel du Cerf de Virginie en hiver est un phénomène répandu dans le nord-est de l'Amérique du Nord. L'addition de nourriture à des points d'alimentation est susceptible d'influencer les activités habituelles des cerfs. Grâce à des repérages télémétriques, nous avons comparé les déplacements et la taille des domaines vitaux de neuf cerfs qui utilisaient des points d'alimentation avec ceux de huit cerfs dont le domaine vital n'en renfermait pas. L'étude a eu lieu en 1995 dans le ravage de Pohénégamook, à la limite nordique de l'aire de répartition de l'espèce. La superficie utilisée par les cerfs qui fréquentaient les mangeoires ne différait pas significativement de celle des autres cerfs (42 vs 39 ha). Les cerfs ont eu tendance à rester plus près des auges au début de l'hiver qu'à la fin, mais leur domaine vital n'a pas varié durant la période d'étude. Ainsi, au cours d'un hiver où l'enneigement fut moyen, un nourrissage artificiel des cerfs de Virginie fournissant environ le tiers de leurs besoins alimentaires n'a pas modifié substantiellement leur patron d'utilisation de l'espace dans un ravage où la compétition pour la nourriture était intense.

Mots clefs: Cerf de Virginie, *Odocoileus virginianus*, domaine vital, nourrissage, hiver, Québec.

Winter feeding of White-tailed Deer has become very common in northeastern North America. Food addition at feeding sites can modify the usual activity pattern of deer. Using telemetry, we compared home-range size and movements of nine deer that used feeding areas with those of eight animals that did not have access to artificial food. Winter home range size did not differ significantly between deer attending feeding sites (42 ha) and those which depended only on natural food (39 ha). Deer frequenting feeding areas tended to stay closer to feeders during the first half of the winter than the second, but this behaviour did not affect their home range size. Artificial feeding of White-tailed Deer providing approximately one third of their food requirements did not change markedly their pattern of space use during a winter with average snowfall in a wintering area where competition for food was intense.

Key Words : White-tailed Deer, *Odocoileus virginianus*, feeding, home range, winter, Québec.

En Amérique du Nord, on a observé, au cours des dernières décennies, une augmentation de la distribution de fourrage et de moulée comme aliment d'appoint ou d'urgence aux populations de Cerf de Virginie (*Odocoileus virginianus*) (Voigt 1990; McBryde 1995). Cette pratique concentre les cerfs autour des sites d'alimentation, ce qui pourrait entraîner des effets néfastes sur les animaux et leur habitat: concentration des prédateurs (Ozoga 1972), augmentation du stress et des comportements agressifs (Grenier 1997), possibilité d'un accroissement de la transmission de maladies (Gagnon 1991), et pression de broutement plus élevée autour des mangeoires (Doenier et al. 1997).

Les cerfs nordiques migrent, de façon traditionnelle, de leur domaine vital estival vers leur aire d'hivernage au début de chaque hiver (Tierson et al. 1985; Mooty et al. 1987; Lewis et Rongstad 1998); ils retournent dans la même partie de l'aire d'hivernage année après année et se montrent très fidèles à leur domaine vital (L. Lesage, données non publiées). Dans les ravages, les cerfs entretiennent un réseau de sentiers qui réduit les coûts de locomotion (Dumont et al. 1998) et facilite l'évitement des prédateurs (Messier et Barrette 1985). Non seulement l'aire utilisée par les animaux est considérablement réduite par rapport à l'été (ex. Tierson et al. 1985), mais elle peut varier d'un hiver à l'autre selon la sévérité des conditions environnementales (Drolet 1976). Durant cette saison, les cerfs nordiques occupent des domaines vitaux généralement inférieurs à 50 ha (Nelson et Mech 1981; Mooty et al. 1987). La quête de nourriture est alors responsable des principaux déplacements des cerfs et la locomotion dans la neige épaisse représente la plus grande dépense d'énergie (Telfer 1970; Parker et al. 1984). Les cerfs choisissent de faire face à la rigueur de l'hiver en conservant leur énergie par la diminution du niveau général d'activité, ce qui leur permet de minimiser les pertes de réserves corporelles, plutôt que d'augmenter les dépenses d'énergie en mangeant plus de ramilles pour combler les besoins métaboliques (Silver et al. 1969; Ozoga et Verme 1970; Moen 1976; A. Dumont, données non publiées). Il devient donc avantageux d'utiliser une source de nourriture riche et spatialement concentrée. Les observations de Doenier et al. (1997) concernant le broutement plus grand des ramilles autour des points d'alimentation, suggèrent soit une diminution du domaine vital chez les cerfs utilisant de la nourriture distribuée de façon artificielle, soit une concentration des animaux à leur pourtour. Tierson et al. (1985) et St-Louis (1998) ont également observé que des branches rendues disponibles à la suite de coupes forestières affectaient l'aire utilisée par les cerfs.

Personne ne s'est encore penché sur l'influence de sites d'alimentation en regard des déplacements des cerfs et de leur domaine vital durant l'hiver. Notre étude visait donc à déterminer l'effet du nourrissage artificiel sur le patron d'utilisation de l'espace de cerfs de Virginie nordiques durant l'hiver. À l'aide de cerfs munis de colliers émetteurs, nous avons vérifié les hypothèses suivantes: (a) les cerfs qui utilisent les points d'alimentation possèdent un domaine vital plus petit que les cerfs n'utilisant que la nourriture naturelle parce qu'ils ont besoin de couvrir une superficie plus restreinte pour maintenir un bilan énergétique équivalent; (b) la période de la journée influence la proximité des cerfs par rapport aux sites d'alimentation artificielle car l'approvisionnement des mangeoires se fait à heure relativement fixe; (c) plus l'enneigement et l'enfoncement des cerfs dans la neige sont élevés, plus les déplacements des cerfs par rapport aux points d'alimentation sont réduits parce que la consommation de nourriture artificielle est plus profitable que la recherche de ramilles.

Matériel et méthode

L'étude a eu lieu dans le ravage de Pohénégamook qui est situé à 250 km à l'est de la ville de Québec (Figure 1). Ce ravage, qui s'étend le long du côté est du lac Pohénégamook, possède un relief variant entre 200 et 600 m d'altitude et couvre environ 25 km^2. Le Sapin baumier (*Abies balsamea*) et l'Épinette blanche (*Picea glauca*) colonisent les stations basses ou à drainage lent. Dans les pentes, le Sapin baumier s'associe au Bouleau jaune (*Betula alleghaniensis*) et au Bouleau à papier (*Betula papyrifera*). L'Érable à sucre (*Acer saccharum*), le Hêtre à grandes feuilles (*Fagus grandifolia*) et le Bouleau jaune dominent sur les sommets (Potvin et al. 1981). La forêt couvre la majeure partie du ravage, les terres en culture ou en friche n'occupant que 10 % de la superficie totale. La population de cerfs atteignait environ 500 animaux au moment de l'étude et elle était stable à cause de la compétition pour la nourriture hivernale (A. Dumont, données non publiées). En plus de la malnutrition, la prédation du coyote (*Canis latrans*) et les collisions causaient plusieurs mortalités hivernales au moment de l'étude (A. Dumont, données non publiées).

Durant l'hiver 1995, une vingtaine de résidents de Pohénégamook nourrissaient les cerfs près de leur demeure, une pratique existant depuis quelques années; environ 20 % de la population de cerfs s'y alimentaient (Grenier 1997). On distribuait près de 7000 kg de nourriture par hiver aux cerfs au moment de l'étude (A. Dumont, données non publiées) et elle se composait principalement de moulée à forte teneur en énergie (Berteaux et al. 1998) et de grain. Pour l'ensemble de l'hiver, chaque cerf fréquentant les mangeoires avait donc accès, en moyenne, à environ 500 g de nourriture artificielle par jour. Trois des quatre points d'alimentation utilisés dans cette étude étaient situés aux abords du village de Pohénégamook, alors que le quatrième était entretenu par le personnel d'une base de plein air (Figure 1). L'un des sites que nous entretenions était entouré de plusieurs autres; nous avons considéré ce groupe comme une seule entité. La forêt autour des sites d'alimentation était fragmentée et composée de Peuplier faux-tremble (*Populus tremuloides*) et de conifères. Les cerfs étaient nourris quotidiennement matin et soir (à l'exception du site d'alimentation de la base de plein air où ils l'étaient uniquement vers 16 h), à raison de 2 kg de moulée pour bouvillon à chaque occasion. Selon Baker et Hobbs (1985), les cerfs peuvent passer d'une moulée à leur nourriture naturelle, plus pauvre, sans éprouver de troubles digestifs.

L'étude s'est poursuivie du 4 janvier au 14 avril 1995; cependant nous avons laissé une période d'acclimatation de trois semaines avant d'entreprendre la prise des données car deux sites d'alimentation expérimentaux furent établis au début de janvier (Grenier 1997). L'hiver a été divisé en deux périodes: du 1er février au 14 mars et du 15 mars au 14 avril, les cerfs quittant le ravage vers la fin d'avril. Des 17 cerfs (8♂, 9♀, dont deux faons) qui avaient été munis d'un collier émetteur en janvier 1994 ou 1995 (A. Dumont, données non publiées), neuf fréquentaient des sites d'alimentation alors que les autres possédaient des domaines vitaux qui n'en comptaient pas. On a déterminé régulièrement la position des animaux marqués par triangulation au sol, à l'aide d'une antenne yagi munie d'une boussole électronique et montée sur un camion (Lovallo et al. 1994). L'observateur prenait trois visées, en 15 min au maximum, dont les azimuts différaient d'au moins 30°; le logiciel LOCATE (Nams 1990) a permis d'estimer la position des cerfs. À l'aide de colliers émetteurs cachés par un observateur indépendant, on a estimé la précision de chaque localisation à 212 m (E.S. = 42; n = 21). Chaque cerf qui fréquentait les mangeoires a été localisé au cours de 24 jours, étalés sur la période de l'étude, à raison de quatre repérages quotidiens espacés de deux heures. L'échantillonnage couvrait également trois blocs

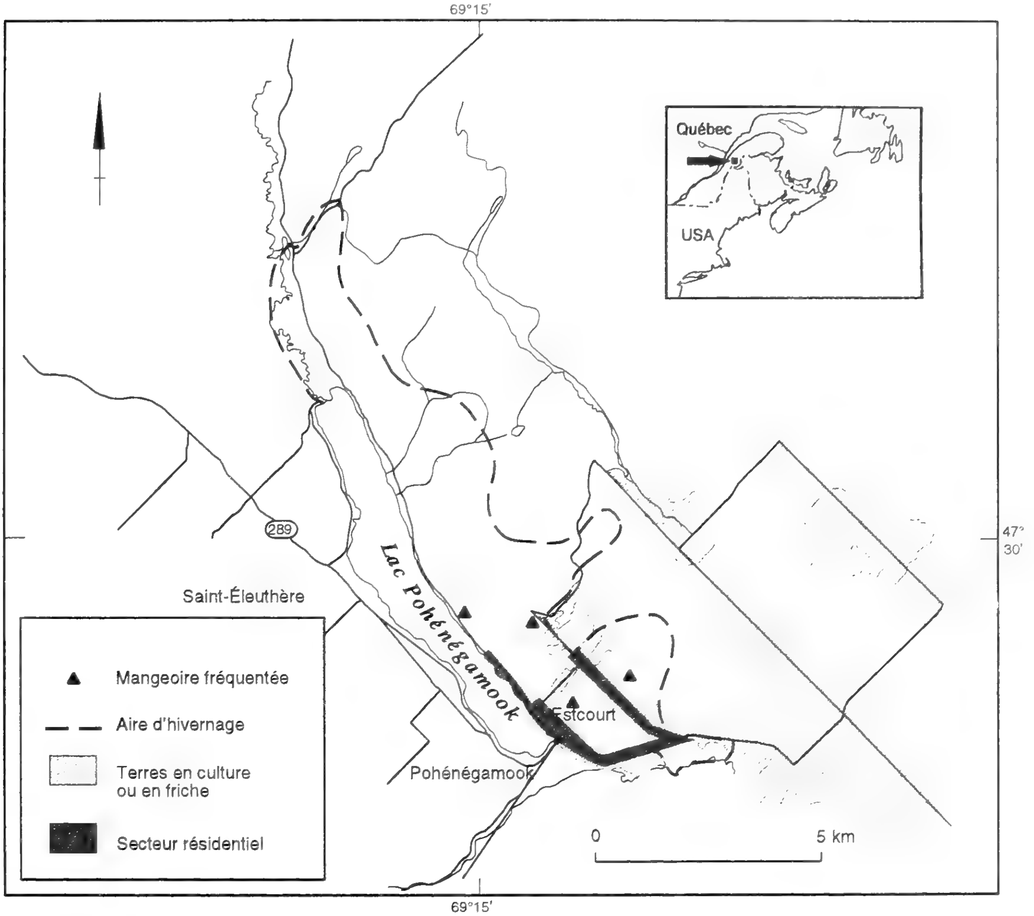

FIGURE 1. Localisation du ravage de cerfs de Virginie de Pohénégamook, dans l'est du Québec, et des quatre sites d'alimentation fréquentés par les cerfs munis de colliers émetteurs durant l'hiver 1995.

d'heure : 0h 01 à 8 h, 8 h 01 à 16 h et 16 h01 à 0 h. Les cerfs qui ne fréquentaient pas les mangeoires furent localisés seulement une ou deux fois par semaine durant le jour; l'addition de localisations nocturnes n'agrandit pas, de façon notoire, les estimations de la taille du domaine vital chez le cerf de Virginie (L. Lesage, données non publiées).

L'évolution des conditions d'enneigement et d'enfoncement a été suivie par un relevé di-hebdomadaire, effectué à une station nivométrique située dans un peuplement mixte du ravage de Pohénégamook. À cette station, on mesurait l'enneigement depuis 1976. Dix règles métriques ont permis de mesurer l'épaisseur de la neige alors que l'enfoncement fut estimé à l'aide du pénétromètre de Verme (1968).

Analyse statistique

La taille des domaines vitaux a été estimée à l'aide de la méthode du polygone convexe minimum à 95 % et de la méthode des noyaux à 95 % (0,6 Lscv) (Worton 1989), en utilisant le logiciel Calhome (Kie et al. 1996). Nous nous sommes assurés d'avoir au moins 30 observations pour utiliser la methode des noyaux (Anderson 1982). Nous avons comparé la superficie des domaines vitaux grâce au test de t de Student (Scherrer 1984). Comme les cerfs fréquentant les mangeoires firent l'objet d'environ cinq fois plus de localisations que les autres cerfs, nous avons repris le calcul de leur domaine vital pour l'ensemble de l'hiver en ne retenant qu'une position sur cinq. Nous avons déterminé si la période de l'hiver, la période du jour ou l'individu influençaient la distance séparant les cerfs des sites d'alimentation, grâce à une analyse de variance. Comme il fut impossible d'obtenir, pour cette analyse, la normalité des résidus par transformations mathématiques, nous avons effectué une ANOVA sur les valeurs de distance converties en rang (Conover et

Berteaux 1980). La similarité des résultats de l'ANOVA obtenus sur les valeurs originales et celles transformées en rang nous a permis d'utiliser les conclusions de l'analyse faite avec les données orignales (Conover et Berteaux 1980). Nous avons utilisé le progiciel SAS (SAS Institute 1985) pour effectuer les analyses statistiques.

L'intervalle de deux heures qui séparait certaines paires de localisations pourrait avoir causé un problème d'autocorrélation entre les données. Cependant, la distribution des localisations de mouvements des animaux suit rarement une distribution normale parce que les mouvements reflètent une décision comportementale. Selon McNay et al. (1994) et Rooney et al. (1998), il vaut mieux effectuer les repérages de façon systématique à travers le temps plutôt que de chercher à obtenir un intervalle qui permet une indépendance statistique des données. De plus, selon Raynolds et Laundre (1990), un intervalle court permet d'obtenir une estimation valide du domaine vital. Pour ces raisons, nous n'avons rejeté aucune localisation à cause d'une trop grande proximité temporelle.

Résultats

Par rapport aux 20 dernières années, la rigueur de l'hiver 1995 s'approcha de la normale puisque l'enneigement et l'enfoncement cumulatifs atteignirent 5829 j-cm et 4116 j-cm, respectivement; les normales correspondantes sont 6655 j-cm et 4647 j-cm. La première moitié de l'étude (début de février à la mi-mars) a connu des conditions plus rigoureuses que la seconde (Figure 2). En effet, l'enfoncement a dépassé 50 cm en tout temps et l'enneigement moyen a dépassé 70 cm, alors qu'à la mi-mars l'épaisseur de la neige commença à diminuer de façon importante et régulière. Durant cette dernière période, l'enfoncement chuta rapidement avec la venue d'une pluie, le 25 mars, qui provoqua la formation d'une couche de glace.

Au total, 734 localisations furent obtenues pour les neuf cerfs fréquentant les mangeoires, comparativement à 128 repérages pour les cerfs n'utilisant pas les points d'alimentation; il y eut très peu de variation dans la fréquence de repérage des animaux suivis. La taille moyenne du domaine vital des cerfs qui fréquentaient les points d'alimentation (59 ha), calculée sur l'ensemble de l'hiver selon la méthode du polygone convexe, ne différait pas significativement (t = 1,11; dl = 15; p = 0,29) de celle des cerfs qui n'utilisaient pas la nourriture artificielle (39 ha: Tableau 1). En ne retenant qu'une localisation sur cinq (n = 144), le domaine vital des cerfs fréquentant les mangeoires couvrait, en moyenne, 42 ha

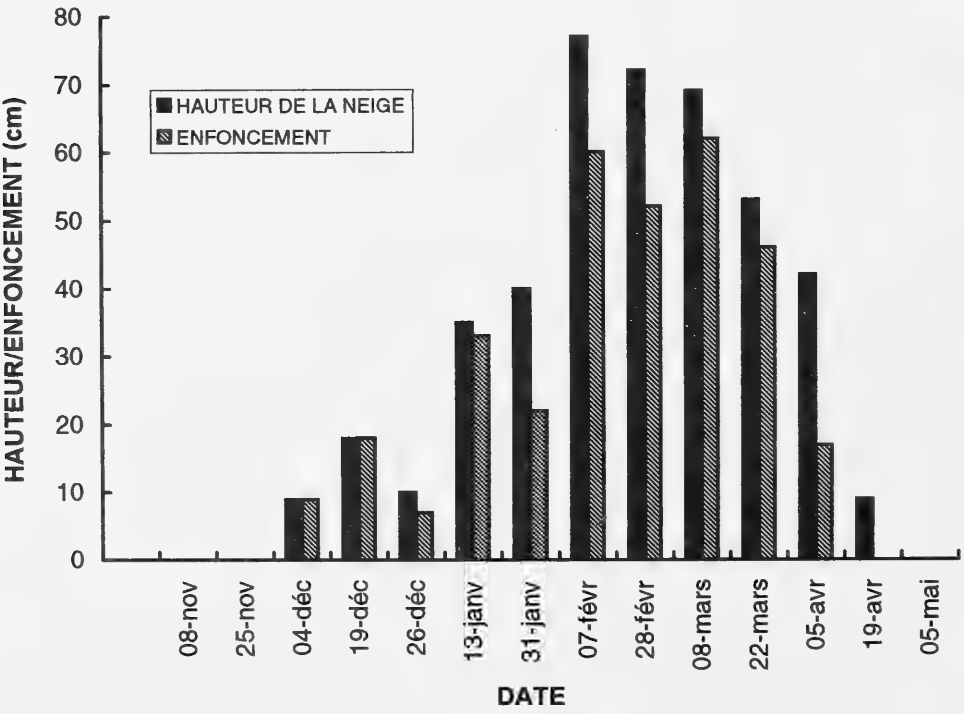

FIGURE 2. Hauteur de la neige et enfoncement des cerfs au cours de l'hiver 1995 dans le ravage de Pohénégamook, est du Québec.

TABLEAU 1. Taille (ha) des domaines vitaux de cerfs de Virginie du ravage de Pohénégamook au cours de l'hiver 1995, selon qu'ils utilisaient ou non des sites d'alimentation artificielle. Deux estimateurs de l'aire occupée (polygone convexe (PC) et noyaux à 95 %) ont été utilisés lorsque les conditions minimales étaient rencontrées.

	1er février–14 mars		15 mars–14 avril		Ensemble de l'hiver
Utilisation des auges	PC	Noyaux	PC	Noyaux	PC
oui	40 (13; 9)[a]	71 (23; 9)	48 (6; 9)	62 (10; 9)	59 (11; 9)
non	N.D.[b]	N.D.	N.D.	N.D.	39 (15; 8)

[a]Écart-type de la moyenne; nombre de cerfs.
[b]Non disponible; nombre de localisations trop faible.

(E.S. = 8; n = 9), ce qui ne diffère pas non plus de la superficie moyenne occupée par les cerfs de l'autre groupe (t = 0,24; dl = 15; p > 0,75). La méthode de Kernel produisit une estimation supérieure de la taille moyenne du domaine vital que la méthode du polygone convexe. Cependant, la taille des domaines vitaux des cerfs qui fréquentèrent les points d'alimentation ne varia pas significativement durant les deux périodes de l'hiver, indépendamment de la méthode d'estimation (PC: t = 0,54; dl = 16; p = 0,60; noyaux: t = 0,34; dl = 16; p = 0,74) (Tableau 1).

La distance séparant les cerfs des sites d'alimentation a varié au courant de l'hiver. Les cerfs ont eu tendance à se tenir légèrement plus près des mangeoires à la première qu'à la deuxième période (Tabeau 2). Cependant, l'ANOVA a révélé une interaction significative (F = 4,04; dl = 2; p < 0,05) entre l'heure de la journée et la période de l'hiver. Au début de l'hiver, les cerfs furent à une plus courte distance des auges durant la nuit que le jour, soit de 8 h à 16 h, alors que cette tendance s'inversa pendant la deuxième période. La plupart des animaux qui utilisèrent les sites d'alimentation ne s'éloignèrent pas à plus de 600 m de ceux-ci. De façon générale, les cerfs firent preuve d'une grande variabilité individuelle dans leur utilisation de l'espace, les estimations de domaine vital et de distance possédant des coefficients de variation approchant parfois 100 %.

Discussion

Contrairement à notre première hypothèse, les cerfs du ravage de Pohénégamook qui utilisaient les points d'alimentation n'ont pas réduit, de façon substantielle, la taille de leur domaine vital par rapport aux cerfs qui consommaient uniquement des ramilles. Les cerfs de Pohénégamook occupaient, par ailleurs, des domaines vitaux hivernaux comparables à ceux observés chez d'autres populations nordiques (44 ha, Nelson et Mech 1981; 43 ha, Mooty et al. 1987). Les cerfs fréquentant les mangeoires n'ont pas réduit la superficie de leur domaine vital au cours d'un hiver moyennement rigoureux en présence d'une forte compétition pour la nourriture même si les mangeoires pouvaient leur fournir environ le tiers de leurs besoins alimentaires (Schmitz 1990; J.-P. Ouellet, données non publiées). Cette tendance s'est maintenue tout au long de l'hiver bien que les conditions d'enneigement fussent beaucoup plus rigoureuses durant la première moitié de la période d'étude que la seconde. Cette indépendance relative face aux mangeoires explique peut-être aussi pourquoi nous fûmes incapables de détecter des mouvements synchronisés des cerfs vers les points d'alimentation.

Nos hypothèses présumaient que deux phénomènes pouvaient amener une concentration des cerfs aux sites d'alimentation : l'entravement causé par la neige et le stress nutritionnel. Ces facteurs agissent à des moments différents durant l'hiver. C'est souvent en février et mars que l'enneigement est le plus élevé, alors que le stress nutritionnel progresse et atteint son maximum à la fin de l'hiver quand la qualité et la disponibilité des ramilles sont réduites (Moen 1978; Parker et al. 1984; A. Dumont, donées non publiées). L'enneigement influence le plus les mouvements des cerfs en hiver et, lorsque l'accumulation dépasse 55 cm, les déplacements et l'aire utilisée par les animaux diminuent (Drolet 1976). Les cerfs répondent aux changements d'enneigement qui prévalent au moment même plutôt qu'à la moyenne de l'hiver. En effet, les cerfs démontrent une stratégie de conservation de l'énergie entre janvier et mars, mais leur activité générale augmente durant la fonte rapide de la neige, en mars et avril (Moen 1976). Il aurait donc été logique d'observer une augmentation de la surface utilisée à la fin de l'hiver puisque les déplacements et la quête alimentaire des cerfs sont facilités par la fonte et le durcissement de la neige alors qu'au même moment, la nourriture se raréfie.

Au ravage de Pohénégamook, la première période (février-mars) de l'hiver 1995 présentait des conditions d'enneigement critiques (plus de 55 cm), qu'on croyait suffisantes pour faire diminuer le domaine vital des animaux. Cependant, bien que les cerfs aient eu tendance à demeurer plus loin des auges durant la deuxième période de l'hiver (Tableau 2), nous n'avons pas observé une augmentation de la superficie utilisée par les cerfs à la fin de la saison hivernale, malgré la formation d'une couche de glace qui les supportait. Il se peut que le fait de ne pas

TABLEAU 2. Distance moyenne (m) séparant neuf cerfs des sites d'alimentation qu'ils fréquentaient régulièrement en fonction de l'heure du jour et de la période de l'hiver, ravage de Pohénégamook, hiver 1995.

Heure	1er février - 14 mars	15 mars - 14 avril	Ensemble de l'hiver
0 h 01-08 h	399 (22)[a]	458 (22)	429 (15)
08 h 01-16 h	492 (22)	461 (25)	477 (17)
16 h 01- 0 h	398 (21)	499 (27)	448 (17)

[a] Écart-type de la moyenne.

avoir nourri les cerfs à volonté ait diminué l'effet de concentration aux sites d'alimentation. Cependant, Schmitz (1990) a observé que même dans le cas où la nourriture artificielle était fournie *ad libitum*, les cerfs continuaient quand même à consommer leur nourriture naturelle tout au long de l'hiver. Chez des cerfs ayant accès à une quantitié illimitée de nourriture artificielle, Doenier et al. (1997) ont par ailleurs observé que la sévérité de l'hiver influença beaucoup l'utilisation de la nourriture artificielle, et que les animaux consommèrent davantage de moulée à la fin de l'hiver. Pour l'ensemble de l'hiver, les cerfs de Pohénégamook qui fréquentaient les mangeoires n'ont pas restreint leurs déplacements davantage que ceux qui ont consommé uniquement des ramilles. Ainsi, il est plausible de croire qu'ils n'ont pas été trop pris au dépourvu quand l'approvisionnement des mangeoires cessa au printemps. Le patron d'utilisation de l'espace des cerfs pourrait, par contre, s'expliquer par le modèle de distribution idéale libre des animaux (Fretwell et Lucas 1970). Comme les cerfs sont incapables de contrôler l'accès aux mangeoires (Grenier 1997), les points d'alimentation concentreraient les animaux. Cette augmentation de la densité locale accentuerait la compétition pour les ramilles autour des mangeoires, forçant les cerfs à couvrir une plus grande superficie pour combler leur besoin de ramilles.

L'entretien annuel de points d'alimentation dans un ravage de cerf a vraisemblablement comme effet d'accroître la pression de broutage sur la végétation entourant ces sites (Doenier et al. 1997). Les cerfs sont en effet très traditionnels dans l'utilisation de leurs domaines vitaux saisonniers et retournent chaque année dans la même partie du ravage (L. Lesage et al., données non publiées). Comme à Pohénégamook la nourriture hivernale représente le facteur de régularisation des effectifs (A. Dumont, données non publié), les aliments d'appoint offerts chaque hiver ont vraisemblablement eu comme conséquence d'accroître initialement la densité de cerfs. Ainsi, les animaux furent subséquemment plus nombreux à brouter la végétation entourant les mangeoires dans un rayon de 500 à 600 m, augmentant probablement le taux de broutement des ramilles. À Pohénégamook, les résidents de la ville fournissaient environ 7000 kg d'aliments d'appoint à une centaine de cerfs au moment de l'étude (A. Dumont, données non publiées). Nos résultats, tout comme ceux de Lewis et Rongstad (1998), suggèrent que, dans de telles conditions, le nourrissage d'appoint des cerfs de Virginie n'a pas modifié substantiellement leur utilisation de l'espace. Cependant, compte tenu de la taille limitée de notre effectif qui affecte la puissance de notre analyse statistique, il serait souhaitable que l'on reprenne le même genre d'étude ailleurs dans le nord-est du continent américain.

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Littérature citée

Anderson, D. J. 1982. The home-range: a new nonparametric estimation technique. Ecology 63: 103–112.

Baker, M. C., et **N. T. Hobbs.** 1985. Emergency feeding of mule deer during winter: test of a supplemental ration. Journal of Wildlife Management 49: 934–942.

Berteaux, D., M. Crête, J. Huot, J. Maltais, et **J.-P. Ouellet.** 1998. Food choice by white-tailed deer in relation to protein and energy content of the diet: a field experiment. Oecologia 115: 84–92.

Conover, W. J., et **D. Berteaux.** 1980. Practical nonparametric statistics. 2e édition. Wiley series in probability and mathematical statistics. John Wiley and Sons, New York. 493 pages.

Doenier, P. B., G. D. Delguidice, et **M. R. Riggs.** 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25: 235–243.

Drolet, C. A. 1976. Distribution and movements of white-tailed deer in southern New Brunswick in relation to environmental factors. Canadian Field-Naturalist 90: 123–136.

Dumont, A., J.-P. Ouellet, M. Crête, et **J. Huot.** 1998. Caractéristiques de peuplements forestiers recherchés par le cerf de Virginie en hiver à la limite nord de son aire de répartition. Canadian Journal of Zoology 76: 1024–1036.

Fretwell, S. D., et **H. L. Lucas.** 1970. On territorial behavior and other factors influencing habitat distribution in birds. Acta Biotheoretica 19 : 16–36.

Gagnon, L. 1991. Nourrissage du cerf de Virginie: revue de littérature. Ministère du Loisir, de la Chasse et de la Pêche, Québec, 112 pages.

Grenier, D. 1997. Accès à la nourriture chez des cerfs de Virginie (*Odocoileus virginianus*) fréquentant des sites d'alimentation hivernaux de la région du Bas-Saint-Laurent. Thèse de Maîtrise, Université Laval, Québec. 64 pages.

Kie, J. G., J. A. Baldwin, et **C. J. Evans.** 1996. CALHOME: a program for estimating animal home ranges. Wildlife Society Bulletin 24: 342–344.

Lovallo, M. J., K. C. Vercauteran, N. C. Hedge, E. M. Anderson, et **S. E. Hygnstrom.** 1994. An evaluation of electronic versus hand-held compasses for telemetry studies. Wildlife Society Bulletin 22: 662–667.

Lewis, T. L., et **O. J. Rongstad.** 1998. Effects of supplemental feeding on white-tailed deer, *Odocoileus virginianus*, migration and survival in northern Wisconsin. Canadian Field-Naturalist 112 : 75–81.

McBryde, G. L. 1995. Economics of supplemental feeding and food plots for white-tailed deer. Wildife Society Bulletin 23: 497–501.

McNay, R. S., J. A. Morgan, et **F. L. Bunnell.** 1994. Characterizing independence of observations in movements of Columbian black-tailed deer. Journal of Wildlife Management 58: 422–429.

Messier, F., et **C. Barrette.** 1985. The efficiency of yarding behavior by white-tailed deer as antipredator strategy. Canadian Journal of Zoology 64: 1134–1136.

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57: 192–198.

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. Journal of Wildlife Management 42: 715–738.

Mooty, J. J., P. D. Karns, et **T. K. Fuller.** 1987. Habitat use and seasonal range size of white-tailed deer in Northcentral Minnesota. Journal of Wildlife Management 51: 644–648.

Nams, V. O. 1990. Locate II user's guide. Pacer Inc., Truro, Nova Scotia. 84 pages.

Nelson, M. E., et **L. D. Mech.** 1981. Deer social organization and wolf predation in northeastern Minnesota. Wildlife Monographs 77. 53 pages.

Ozoga, J. J., et **L. J. Verme.** 1970. Winter feeding patterns of penned white-tailed deer. Journal of Wildlife Management 34: 431–439.

Ozoga, J. J. 1972. Agressive behavior of white-tailed deer at winter cuttings. Journal of Wildlife Management 36: 861–868.

Parker, K. L., C. T. Robbins, et **T. A. Hanley.** 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48: 474–488.

Potvin, F., J. Huot, et **F. Duchesneau.** 1981. Deer mortality in Pohénégamook wintering area, Québec. Canadian Field-Naturalist 95: 81–84.

Reynolds, T. D., et **J. W. Laundre.** 1990. Time intervals for estimating pronghorn and coyote home ranges and daily movements. Journal of Wildlife Management 54: 316–322.

Rooney, S. M., A. Wolfe, et **T. J. Hayden.** 1998. Autocorrelated data in telemetry studies: time of independence and the problem of behavioural effects. Mammal Reviews 28: 89–98.

SAS Institute Inc. 1985. SAS user's guide: statistics, version 6. SAS Institute, Cary, North Carolina. 1028 pages.

Scherrer, B. 1984. Biostatistique. Gaétan Morin éditions, Chicoutimi, Québec. 850 pages.

Schmitz, O. J. 1990. Management implications of foraging theory: evaluating deer supplemental feeding. Journal of Wildlife Management 54: 522–532.

Silver, H., N. F. Colovos, J. B. Holter, et **H. H. Hayes.** 1969. Fasting metabolism of white-tailed deer. Journal of Wildlife Management 33: 490–498.

St-Louis, A. 1998. Réaction du cerf de Virginie lors d'opérations forestières commerciales réalisées dans un ravage en hiver. Mémoire de maîtrise, Université du Québec à Rimouski. 58 pages.

Tierson, W. C., G. F. Mattfield, R. W. Sage, et **D. F. Behrend.** 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. Journal of Wildlife Management 49: 760–769.

Telfer, E. S. 1970. Winter habitat selection by moose and white-tailed deer. Journal of Wildlife Management 34: 553–559.

Verme, L. J. 1968. An index of weather severity for northern deer. Journal of Wildlife Management 32: 566–574.

Voigt, D. R. 1990. White-tailed deer in Ontario: background to a policy. Ontario Ministry Natural Resources. 106 pages.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164–168.

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The Dispersal of Fruits and Seeds of Poison-ivy, *Toxicodendron radicans*, by Ruffed Grouse, *Bonasa umbellus*, and Squirrels, *Tamiasciurus hudsonicus* and *Sciurus carolinensis*

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Rodney Penner, G. Eric E. Moodie, and Richard J. Staniforth. 1999. The dispersal of fruits and seeds of Poison-ivy, *Toxicodendron radicans*, by Ruffed Grouse, *Bonasa umbellus*, and squirrels, *Tamiasciurus hudsonicus* and *Sciurus carolinensis*. Canadian Field-Naturalist 113(4): 616–620.

A study was conducted to determine the dispersal potential of seeds and fruits of Poison-ivy (*Toxicodendron radicans* (L.) Rydb.) by mammals and birds in a study plot near Stonewall, Manitoba, Canada. Ruffed Grouse (*Bonasa umbellus*) and Red Squirrels (*Tamiasciurus hudsonicus*) and Grey Squirrels (*Sciurus carolinensis*) were the most common visitors to feeders containing fruits and to fruit-bearing plants. Squirrels acted as seed predators by removing the exocarps and mesocarps from fruits and eating the seeds. However, they often dropped individual fruits or entire infructescences that they had been carrying to dining or caching sites and because of this they were effective dispersal agents for the seeds. Ruffed Grouse behaved as frugivores by eating the fruits and excreting intact seeds. Germination in seeds extracted from grouse faeces was not significantly different from seeds from fruits taken directly from the plants. Germination of seeds from within intact fruit was higher but, not significantly, than that from seeds from which the exocarps and mesocarps had been removed. These results show that the fruit and seeds of Poison-ivy are food resources for Ruffed Grouse and squirrels, respectively. Both kinds of animals are effective seed dispersal agents for seeds of this species.

Key Words: Poison-ivy, *Toxicodendron radicans,* germination, seed dispersal, Red Squirrel, *Tamiasciurus hudsonicus*, Grey Squirrel, *Sciurus carolinensis*, Ruffed Grouse, *Bonasa umbellus*.

Poison-ivy (*Toxicodendron radicans* (L.) Rydb.) is well known for its ability to cause dermatitis in humans. However, cattle and some lepidopterans feed on its leaves with no apparent harmful effects (Looman and Best 1987; R. Westwood, University of Winnipeg, personal communication). The active ingredient in the irritant is 3-n-pentadecylcatechol or urushiol, which is found in all parts of the plant including the fruit (Stephens 1980). Chemical irritants in plants are believed to have an anti-herbivore function, which would have the potential to influence negatively the effectiveness of positive plant-animal interactions, such as pollination and seed dispersal (Cipollini and Levey 1997). On the other hand, immunity to a plant toxin by specific pollinators or seed dispersers would be advantageous to both the animal and the plant. Little is known about the role of animals particularly mammals in the dispersal of the seeds of this species (Gillis 1971).

The fruit of Poison-ivy is a yellow-green, dry, fibrous, single-seeded drupe which has a distinct odour (Gillis 1971; personal observation). It is a low-quality fruit type according to Stiles (1980). Plants are autumn-fruiting, with the dense panicles of fruit persisting on the plants throughout the winter months. These fruit and fruiting characteristics are usually associated with the attraction of mammals, rather than birds (van der Pijl 1972). The seeds of drupes often require the action of the digestive system of an animal dispersal agent before dormancy is broken (van der Pijl 1972; Howe and Smallwood 1982). Poison-ivy seeds are eaten by, or have been observed in the faeces of, Sharp-tailed Grouse (*Tympanuchus phasianellus*), Ruffed Grouse (*Bonasa umbellus*), American Crows (*Corvus brachyrhynchos*), White- tailed Deer (*Odocoileus virginianus*) and Red Fox (*Vulpes vulpes*) (Brown 1946; Krefting and Roe 1949; Lay 1965; Korschgen 1966; Jones and Theberge 1983, respectively), but little is known about the subsequent viability and germination characteristics of such seeds.

The objectives of the present study were to determine: (i) what kinds of animals may remove fruit from Poison-ivy plants, (ii) the germination characteristics of fresh seeds, and (iii) the effect of passage through the gut of a frugivore on the germination of seeds.

Methods

The study area

The study area was located 5 km south of Stonewall, Manitoba, Canada (50°08′N, 97°20′W) within the Parkland vegetation zone (Scott 1995). The study plot was located in a grove of second-growth Bur Oak (*Quercus macrocarpa*) with a well-developed understory, principally dominated by Poison-ivy (*Toxicodendron radicans*).

Preliminary study

A small pilot study was undertaken from 26 October–25 November 1997 to determine what kinds of animals might feed on fruits of Poison-ivy. To do this three feeders were set up. The feeders were plywood boards 0.3 m × 0.3 m with Poison-ivy fruits placed on top. One was placed at 1.5 m above the ground at the top of a wooden pole, set away from nearby trees so climbing animals would have trouble reaching it. Two ground-level feeders were placed on the surface of the snow but one was hidden from above by leaning another piece of plywood over it so that only ground-dwelling animals would find it easily. The third feeder was exposed and visible from the air. A known number of between two and three thousand individual Poison-ivy fruits were placed on each feeder, and the feeders were monitored every 6–7 days so that fruit removal could be recorded. Animal tracks were noted and later used to identify animal visitors. This preliminary study showed that Red Squirrels (*Tamiasciurus hudsonicus*) and possibly Grey Squirrels (*Sciurus carolinensis*) removed some fruit from the feeders, that the feeder located on the ground and hidden from above was most favoured, and that the above-ground feeder was rarely visited. It was also noted that squirrels were much more likely to take fruits from plants rather than from the feeders.

Plot study

Given the findings of the preliminary study, a plot study was designed to investigate the extent and time of fruit removal from living plants. Thirty-eight plants from within a 50 m × 50 m square plot were selected between 27 January and 6 February, 1998 for monitoring. Their locations were indicated by coloured tape on nearby bushes rather than by marking the plants directly. The numbers of fruits per plant were counted on 27 January and 6 February 1998 and thence at 7-day intervals for 49 days. Animal visitors were identified from tracks adjacent to the study plants from which the fruits had been removed. Snow cover let us determine that fruits were being removed rather than simply dropping naturally and lying un-noticed in the leaves and litter. Fresh snow was scraped away when necessary.

Seeds from faeces

In November 1997, the study site was examined for animal faeces which might contain seeds of Poison-ivy. Three locations were found which contained ample amounts of grouse faeces. Ten pellets were collected from each of these locations. Squirrel faeces were also found at the same three locations. The three samples of grouse faeces were combined. Faeces of both species were stored outdoors until germination tests began in March 1998. At that time 275 intact Poison-ivy seeds were extracted from the grouse faeces and provided with the same germination conditions described for treatment (i) and (ii), below. More grouse faeces were collected in March 1998; their seeds were extracted and also put to germinate under the same conditions as described for treatment (i). These two germination trials are described as treatments (vi) and (vii), respectively. None of the squirrel faeces contained intact seeds.

Germination of fresh seeds

Poison-ivy fruits were collected from plants in the study site 19 February 1998 so we could compare seed germination with that of seeds which had been retrieved from faeces of Ruffed Grouse. The seeds were hand-cleaned of exocarps and mesocarps and placed in petri dishes on agar gel. Five additional germination treatments were used to attempt to understand the germination requirements of this species. There were eight replicate petri dishes of 25 seeds each for each treatment and germination tests took place in growth chambers. Treatment (i) consisted of subjecting dishes of fresh seeds to alternating light/dark conditions (i.e. light, 25°C, 14h days/dark, 10°C, 10h nights). Treatment (ii) was similar to treatment (i), except that the dishes were kept in continuous darkness by wrapping them in light-proof plastic. In treatment (iii), fresh seeds were scarified by abrasion with sand-paper and put under the same conditions as treatment (i). Treatment (iv) was similar to treatment (iii) except that the scarified seeds were kept in darkened petri-dishes in the growth chamber. Treatment (v) consisted of germination trials using intact fruit rather than extracted seeds, but otherwise the conditions were the same as for treatment (i). The germination trials were allowed to run for 28 days, during which time the petri dishes were monitored twice weekly and any seedlings counted and discarded.

Results

Plot study

The mean number of fruits per plant was 26 (SD = $\pm$ 10.4) at the beginning of the study on 27 January and 6 February. This had fallen to 1.1 (SD = $\pm$ 6.2) by the end of the monitoring period; i.e., 49 days later. More than 97% of study plants showed some fruit removal during this period. Total fruit removal occurred in 89% of the study plants, whereas other plants (8%) were left with only one or two fruits.

Animal visitors that were identified from tracks or by direct observation in the study plots were: White-tailed Deer (*Odocoileus virginianus*), Red Fox (*Vulpes vulpes*), American Crow (*Corvus brachyrhynchos*), Ruffed Grouse (*Bonasa umbellus*), Red Squirrel (*Tamiasciurus hudsonicus*) and Grey Squirrels (*Sciurus carolinensis*). Migratory birds had already left by the time the study had begun and had not returned by the time of its completion.

There was evidence from tracks and droppings that the grouse and squirrels had been feeding on the fruit. However, the animals responsible for removing 34.2% of the fruits remain unidentified because rain or snow had obscured their tracks. Ruffed Grouse were responsible for most of fruit removal. They had taken fruit from 17 of the 38 marked plants. Ruffed Grouse were seen on four separate occasions feeding on the fruit, and seeds were often visible in their faecal pellets. Squirrels removed single fruits or entire infructescences and either husked the fruits (i.e. removed the mesocarps and exocarps) on the spot or carried them elsewhere to be husked or cached. Fruits which had been carried away by squirrels were often dropped and abandoned. This was particularly evident from the large numbers of abandoned fruit at the bases of oak trees. We assumed that seeds in the fruit that had been husked and eaten were destroyed because only seed fragments were recovered from squirrel faeces.

Germination study

Most seeds found in the grouse faeces were those of Poison-ivy, however there were also a few unidentified seeds. Counts of Poison-ivy seeds in the faecal pellets were high: ten randomly chosen faecal pellets contained a mean of 9.9 (SD = ± 3.07) seeds per pellet. Table 1 shows there were no significant differences in the germination of seeds from grouse droppings (treatments vi, vii) when compared with those collected directly from fruit (treatments i and ii) $Chi^2_{(1df)} = 1.0$, $p > 0.25$ and $Chi^2_{(1df)} = 1.0$, $p > 0.99$, respectively). Complete darkness did not have a significant effect on seed germination (treatments i versus ii, iii versus iv, and vi versus vii). Seeds scarified with sand paper (treatments iii and iv) showed significantly better germination than non-scarified seeds (treatments i and ii: $Chi^2_{(1df)} = 19.9$, $p < 0.0005$). The artificially scarified seeds were noticeably more abraded than those which had passed through the digestive tracts of the grouse. The germination of seeds from within fruit (treatment v) was not significantly better than germination in seeds from fruits whose exocarps and mesocarps had been removed, in treatments i and ii.

Discussion

Seeds of Poison-ivy appear to be adapted to two dispersal mechanisms. This study showed that viable seeds of Poison-ivy were dispersed by both Ruffed Grouse and squirrels by means of endozoochory and directed dispersal (Howe and Smallwood 1982), respectively. The grouse are frugivores; i.e., they eat the fruit without destroying the seed, whereas squirrels are primarily seed predators, destroying most of the seeds they eat but dropping many and caching some of them. Analysis of faeces and the results of germination tests showed that seeds were destroyed by passage through squirrels but neither harmed nor aided by digestive systems of grouse. However, seeds that had been carried and then dropped by squirrels were possibly at an advantage because germination from within intact fruits was higher (but not significantly so) than from those that had been extracted from grouse faeces.

Dispersal by Ruffed Grouse

Data from our experiments showed that although Ruffed Grouse are capable of dispersing viable Poison-ivy seeds by endozoochory they do not influence their germinability. This supports a statement by Howe (1986) that few highly frugivorous birds actually scarify seeds and, if they do so, it is an example of unsuccessful digestion rather than an example of a mutualistic compromise with the plant. The overall effect of Ruffed Grouse on dispersal of Poison-ivy seeds is positive as the seeds are deposited at new sites where colonization may occur.

Winter-fruiting plant species often rely on irregular movements of winter frugivores for seed disper-

TABLE 1. Germination responses in seeds of Poison-ivy. (n = eight replicates of 25 seeds per treatment.)

Treatment number	Seed pretreatment	Germination conditions	% germination (Mean & SD)
i	removed from fruit	14h:25°C, light;10h:10°C, dark	$12.5^{a} \pm 7.2$
ii	removed from fruit	14h:25°C, dark;10h:10°C, dark	$16.0^{a} \pm 6.7$
iii	removed from fruit and scarified	14h:25°C, light;10h:10°C, dark	$41.0^{c} \pm 17.7$
iv	removed from fruit and scarified	14h:25°C, dark;10h:10°C, dark	$35.5^{b,c} \pm 8.9$
v	none, seeds left within fruit	14h:25°C, light;10h:10°C, dark	$23.5^{a,b} \pm 10.0$
vi	seeds extracted from grouse faeces	14h:25°C, dark;10h:10°C, dark	$16.0^{a} \pm 4.3$
vii	seeds extracted from grouse faeces	14h:25°C, light;10h:10°C, dark	$14.0^{a} \pm 8.0$

Mean values associated with the same letter are not significantly different (p < 0.05).

sal throughout the winter months (Thompson and Willson 1979). In Virginia, Ruffed Grouse increased their use of soft fruits until late December. Use then declined in January (Norman and Kirkpatrick 1984). Grouse concentrated their feeding on Poison-ivy fruits between August and October (Korschgen 1966) in Missouri, but in Manitoba, we found that most fruits were removed from plants between late January and early March.

It is not known whether Ruffed Grouse can inactivate urushiol. Grouse can utilize conifer leaves as food despite their toxicity. However, there is a limit to the quantity that can be digested due to an accumulation of toxins (Hewitt and Kirkpatrick 1997). The nutritional content of Poison-ivy fruits is low (Stiles 1980). Therefore grouse would need to eat large numbers of fruit to meet energy and nutritional demands (Stiles 1980). This would lead to longer foraging times and may result in high densities of grouse in certain localities where Poison-ivy is common (Hewitt and Kirkpatrick 1996).

Dispersal by squirrels

Poison-ivy fruits were a common food source for squirrels within the study plot. The numbers and rates of fruit removal indicated that the toxicity or noxious properties of Poison-ivy were not great challenges to the squirrels. Squirrels removed and ate individual fruits and dug in the snow to reach buried plants which bore fruit. There was also evidence that they removed entire infructescences. Our observation of large numbers of fruits and infructescences dropped at the bases of oak trees within the study area is supported by the findings of Talley et al. (1996). This could account for the frequent occurrence of Poison-ivy plants found growing in close association with Bur Oak trees.

In the present study, caching Poison-ivy fruits by squirrels was not observed directly; however, the removal of such large numbers of fruits suggested that many were likely to have been cached. Seeds cached by rodents are often forgotten. Others which are cached for insurance may not be used, or the animals may die (Smith and Reichman 1984; Price and Jenkins 1986). The unusual ability of Poison-ivy seeds to germinate without prior removal of the exocarps and mesocarps may be an adaptation for dispersal by caching.

The use of Poison-ivy as a food source for animals has gone largely unnoticed and rarely been studied. This may be partly due to its noxious qualities and difficulties in handling the plants. The present study found that Poison-ivy may be an important seasonal food source for certain animals, such as Ruffed Grouse and squirrels. Reports of a partridge killed while its crop was completely filled with Poison Ivy fruits supports this conclusion (Mulligan and Junkins 1977). This study also shows that the seeds are adapted to survive passage through the digestive tracts of Ruffed Grouse. The presence of the persistent exocarp and mesocarp did not inhibit germination in seeds of intact fruits which were dropped, lost or cached by seed predators such as squirrels. There was no indication that other species present in the study area such as the Red Fox, White-tailed Deer, and American Crow were consuming Poison-ivy fruits despite reports in the literature that they do so.

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Literature Cited

Brown, C. P. 1946. Food of Maine Ruffed Grouse by seasons and cover types. Journal of Wildlife Management 10: 17–28.

Cipollini, M. L., and **D. J. Levey.** 1997. Secondary metabolites of fleshy vertebrate-dispersed fruits: adaptive hypotheses and implication for seed dispersal. American Naturalist 150: 346–372.

Gillis, W. T. 1971. The systematics and ecology of Poison Ivy and the Poison-Oaks (*Toxicodendron*, Anacardiaceae). Rhodora 73: 72–159, 161–237, 370–443, 465–540.

Hewitt, D. G., and **R. L. Kirkpatrick.** 1996. Forage intake rates of Ruffed Grouse and potential effects on grouse density. Canadian Journal of Zoology 74: 2016–2024.

Hewitt, D. G., and **R. L. Kirkpatrick.** 1997. Ruffed Grouse consumption and detoxification of evergreen leaves. Journal of Wildlife Management 61: 29–139.

Howe, H. F. 1986. Seed dispersal by fruit-eating birds and mammals. Pages 121–191 *in* Seed dispersal. *Edited by* D. R. Murray, Academic Press, Orlando, Florida.

Howe, H. F., and **J. Smallwood.** 1982. Ecology of seed dispersal. Annual Review of Ecology and Systematics 13: 201–228.

Jones, D. M., and **J. B. Theberge.** 1983. Variation in Red Fox (*Vulpes vulpes*), summer diets in northwest British Columbia and southwest Yukon. Canadian Field-Naturalist 97: 311–314.

Korschgen, L. J. 1966. Foods and nutrition of Ruffed Grouse in Missouri. Journal of Wildlife Management 30: 86–100.

Krefting, L. H., and **E. I. Roe.** 1949. The role of some birds and mammals in seed germination. Ecological Monographs 19: 269–286.

Lay, D. W. 1965. Fruit utilization by deer in southern forests. Journal of Wildlife Management 29: 370–375.

Looman, J., and **K. F. Best.** 1987. Budd's flora of the Canadian Prairie Provinces. Publication 1662, Research Branch, Agriculture Canada, Hull, Quebec. 863 pages.

Mulligan, G. A., and **B. E. Junkins.** 1977. The biology of Canadian weeds 23. *Rhus radicans* L. Canadian Journal of Plant Science 57: 515–523.

Norman, G. W., and **R. L. Kirkpatrick.** 1984. Foods, nutrition and condition of Ruffed Grouse in southwestern Virginia. Journal of Wildlife Management 48: 183–187.

Pijl, L. van der. 1972. Principles of dispersal in higher plants. 2nd edition Springer-Verlag, Berlin, Germany. 161 pages.

Price, M. V., and **S. H. Jenkins.** 1986. Rodents as seed consumers and dispersers. Pages 191–235 *in* Seed dispersal. *Edited by* D. R. Murray, Academic Press, Orlando, Florida.

Scott, G. A. J. 1995. Canada's vegetation: a world perspective. McGill-Queen's University Press. Montreal, Quebec. 332 pages.

Smith, C. C., and **O. J. Reichman.** 1984. The evolution of food caching by birds and mammals. Annual Review of Ecology and Systematics 15: 329–351.

Stephens, H. A. 1980. Poisonous plants of the central United States. Regents Press of Kansas. Kansas City. 165 pages.

Stiles, E. W. 1980. Patterns of fruit presentation and seed dispersal. American Naturalist 116: 670–688.

Talley, S. M., R. O. Lawton, and **W. N. Setzer.** 1996. Host preferences of *Rhus radicans* (Anacardiaceae) in a southern deciduous hardwood forest. Ecology 77: 1271–1276.

Thompson, J. N., and **M. F. Willson.** 1979. Evolution of temperate fruit/bird interactions: phenological strategies. Evolution 33: 973–982.

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Prey Remains in Bald Eagle, *Haliaeetus leucocephalus*, Pellets from a Winter Roost in the Upper St. Lawrence River, 1996 and 1997

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Regurgitated pellets of Bald Eagles (*Haliaeetus leucocephalus*) wintering along the upper St. Lawrence River were collected from a roost site during 1996 and 1997. Analysis of the indigestible prey remains in the pellets provided some indication of diet. White-tailed Deer (*Odocoileus virginianus*) were the most frequently encountered food species, occurring in 72 and 67% of the pellets in the two years, respectively. Other food items identified included waterfowl (40% in 1996 and 56% in 1997), fish (12% in 1996 and 28% in 1997) and furbearing mammals (9% in 1996 and 10% in 1997). Thirty and 41% of the pellets contained remains of fish or fish-eating birds in the two years, respectively.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, diet, pellets, St. Lawrence River, Great Lakes.

The Bald Eagle (*Haliaeetus leucocephalus*) was extirpated from the Great Lakes basin by the 1970s, due, in part, to severe reductions in reproductive success resulting from exposure to organochlorine contaminants (Postupalsky 1973; Weimeyer et al. 1984; Bowerman et al. 1994). Although breeding eagle populations in the Great Lakes basin began to rebound following the banning of most organochlorine pesticides in the 1970s, many areas of their former range, particularly along the shoreline of Lake Ontario, remain unoccupied. To determine sources of contaminants to eagles breeding in the Great Lakes watershed, much research has focused on the diets of nestlings (Kozie 1986; Bowerman 1991, 1993; Kozie and Anderson 1991). However, the contribution of the winter diet of adult birds to their contaminant burden has received less attention. Persistent organochlorine contaminants in food consumed during the winter and early spring may be incorporated into eggs, potentially affecting their hatchability and viability of the young. Although immature eagles may migrate down the Mississippi flyway during their first few winters of life, mature eagles (usually 4+ years) typically remain within the basin throughout the year (Bowerman 1993; Grubb et al. 1994). Therefore, the diet of birds wintering in the Great Lakes basin is of importance in determining the contaminant load carried by adult birds into the breeding season. The only comprehensive study of the winter diet of Bald Eagles in the Great Lakes and upper St. Lawrence River region was done by Ewins and Andress (1995) and was based on observations of foraging eagles.

All methods of estimating feeding habits are subject to biases. The use of visual observations of feeding raptors to determine diet may fail to document the use of all food types accurately. Larger, more visible prey items will be more easily seen and identified, whereas smaller items and prey consumed more quickly or in less visible locations, may be missed (Marti 1987; Mersmann et al. 1992). Pellet analysis is biased in that it relies on the presence of incompletely digested portions of prey items for detection. Thus, certain prey species may be underrepresented if they lack indigestible parts and pellet analysis may be most effectively used to provide a qualitative picture of the diet, providing approximate indications of relative proportions within the diet (Mersmann et al. 1992). Because neither method adequately documents all food types, Mersmann et al. (1992) conclude that accurate assessment of Bald Eagle diet is best done using all available techniques. In an attempt to augment existing observational information on the winter diet of Bald Eagles in part of the lower Great Lakes basin (Ewins and Andress 1995), regurgitated pellets were collected and analysed for two winters at a communal winter roost on islands in the upper St. Lawrence River.

Study Area and Methods

This study was part of a larger on-going monitoring effort investigating the distribution and movements of wintering Bald Eagles in the St. Lawrence River region by New York State Department of Environmental Conservation (NYSDEC). This study

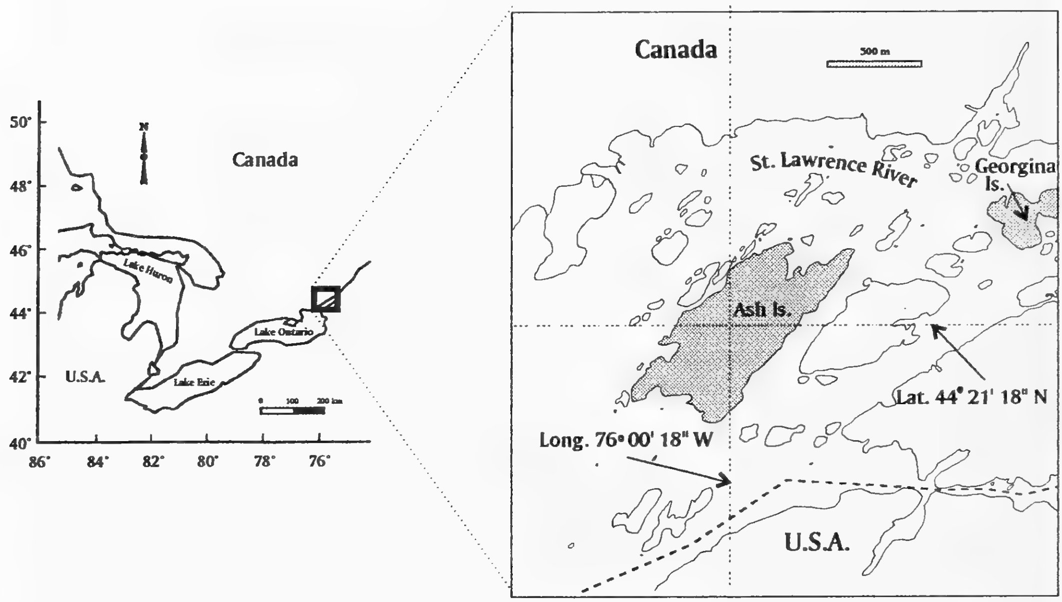

FIGURE 1. Location of Ash and Georgina islands, Thousand Islands, in the upper St. Lawrence River.

involves the use of radio telemetry and aerial and ground surveys. In the St. Lawrence River at Gananoque, Ontario, the current is strong enough to keep the water open throughout the winter, providing access to fish, presumably enabling eagles to overwinter. Eagles normally occur there from early November to early April (B. Andress, personal observation), but are not known to nest (Hunter and Baird 1995). A communal roost on Ash Island (latitude 44°21'18"N, longitude 76°00'18"W; Figure 1), situated 1 km west of the Canadian span of the Thousand Islands bridge, was initially located from the Skydeck observation tower on Hill Island when 11 eagles were seen flying into a stand of trees on 4 March 1995. The roost consisted of a stand of mature White Pines (*Pinus strobus*) stretching about 100 m along the southeast shoreline of Ash Island. On 16 March 1996, one eagle was observed flying into this roost at dusk and three NYSDEC radioed birds were also located at the roost using telemetry. A mature eagle was observed at the Ash Island roost as late as the evening of 20 April 1996. In 1997, nine Bald Eagles were observed using the Ash Island roost, as well as the southwest shoreline of Georgina Island, on March 22 (D. Pilon, personal communication). On the same day radio signals were received at dusk from eagles approximately 4 km southwest of the Ash Island roost site (B. Town, NYSDEC, personal communication). Ash and Georgina Islands are less than 1 km apart and considered to be part of the same roosting area. These roosts are approximately 1-2 km from permanently open areas of swift water on the St. Lawrence River. In addition to the aquatic food sources available from these areas of open water, White-tailed Deer (for scientific names of dietary species see Table 1) are known to move across the ice between islands in this area, and carcasses are frequently available. Some carcasses had been set out during a joint trapping effort between NYSDEC and Parks Canada; numerous other deer were killed by Coyotes (*Canis latrans*) or had fallen through thin ice.

Bald Eagle pellets were collected 21 April 1996 (n = 43) on Ash Island, and 14 April 1997 on Ash (n = 139) and Georgina (n = 9) islands. Discreet pellet samples were readily discernible, being tightly bound together with hair or feathers, and were bagged individually in the field and frozen until analysis. All samples from the 1996 collection were analyzed; a subsample of 39 pellets was selected for detailed analysis from the 1997 collection. Pellets were sorted visually based on their primary components (e.g., hair or feathers); proportional subsamples were selected randomly from within each group.

Pellets were air dried and dissected. Samples of hair, feathers, scales and bones to be identified were set aside. Feather samples were washed and dried according to the procedure described by Sabo and Laybourne (1994). Scales and bones were also washed to facilitate identification.

Guard hairs from White-tailed Deer were identified by visual comparison with hairs of known identity provided by Ontario Ministry of Natural Resources (OMNR, Peterborough, Ontario) and the

Royal Ontario Museum (Toronto, Ontario). Other hairs were examined for identification using procedures described by Adorjan and Kolenoski (1969). We identified feathers by comparison with study skins at the Royal Ontario Museum. Bones were identified by staff at the Royal Ontario Museum. Loose fish scales were identified by comparison to samples of known identity provided by the Canadian Wildlife Service.

Results

In 1996, 33 (77%) of the 43 pellets contained predominately hair. The remaining ten (22%) consisted primarily of feathers. Fourteen pellets (33%) contained both hair and feathers. Only four pellets (9%) contained no hair. Only ten (23%) pellets contained a few small bones. In 1997, 25 (64%) of the subsample of pellets contained primarily hair, 14 (36%) consisted predominantly of feathers, reflecting the proportions of the entire sample of 148 pellets. Both hair and feathers were found in 12 (31%) pellets, and nine (23%) pellets contained remains of fish, mammals and birds. Unlike 1996, 23% of the pellets did not contain hair of any kind, and 49% contained bone or bone fragments. The prey remains identified in the pellets are presented in Table 1. The most commonly identified food species in both years was White-tailed Deer. Although a large proportion of pellets contained unidentified hair, most of these were underhair which, unlike guard hair, cannot be identified to species (D. Joachim, OMNR, personal communication). However, deer guard hairs were identified in all but four of these pellets in 1996 and one in 1997, suggesting that the underhair also came from deer. Ducks were the next most common food item identified in the pellets, with Common Merganser and Wood Duck remains most commonly observed. Few fish remains were found in the pellets; all of these were bones. Muskrat bones were identified in four pellets and the hairs of three other fur-bearing mammals were identified in other pellets. One pellet in 1997 contained a Raccoon claw and underfur.

Discussion

Bald Eagles are known to have diverse diets in the winter, opportunistically utilising whatever abundant food resource is available. Eagles wintering inland in southern Ontario relied heavily on garbage at municipal dumps and deer carcasses (Ewins and Andress 1995), and those wintering in inland Maine consumed starved or road-killed deer, cows and Moose (Todd et al. 1982). Waterfowl, often hunter-crippled, have been reported to provide an important food source for wintering Bald Eagles in areas where open water was available (Todd et al. 1982; Lingle and Krapu 1986; Griffin et al. 1982; Frenzel and Anthony 1989; Ewins and Andress 1995). The extensive use of hunter-crippled waterfowl by Bald Eagles wintering in the Fraser valley, British Columbia is evidenced by the repeated occurrence of lead poisoning incidences (Elliott et al. 1992). Our

TABLE 1. The number (%) of Bald Eagle pellets containing the remains of different prey species from winter roosts on Ash and Georgina islands, upper St. Lawrence River. Percent totals > 100% as there were more than one food item per pellet.

Species	Number of pellets (%)	
	1996	1997
Carp (*Cyprinus carpio*)	2 (4.7)	7 (17.9)
Bass (*Micropterus* sp.)	1 (2.3)	0
Rock Bass (*Ambloplites rupestris*)	0	1 (2.6)
Pike (*Esox* sp.)	0	2 (5.1)
Walleye (*Stizostedion* sp.)	0	1 (2.6)
Unidentified fish	2 (4.7)	2 (5.2)
Mallard (*Anas platyrhynchos*)	1 (2.3)	3 (7.7)
Wood Duck (*Aix sponsa*)	5 (11.6)	1 (2.6)
Greater Scaup (*Aythya marila*)	0	2 (5.2)
Common Goldeneye (*Bucephela clangula*)	1 (2.3)	3 (7.7)
Bufflehead (*Bucephela albeola*)	1 (2.3)	0
Common Merganser (*Mergus merganser*)	8 (18.6)	5 (12.8)
Unidentified duck	2 (4.7)	5 (12.8)
Unidentified bird	1 (2.3)	4 (10.2)
Muskrat (*Ondatra zibethicus*)	1 (2.3)	3 (7.7)
Squirrel (Sciuridae)	1 (2.3)	0
Mustelidae	1 (2.3)	0
Raccoon (*Procyon lotor*)	0	1 (2.6)
White-tailed Deer (*Odocoileus virginianus*)	31 (72.1)	26 (66.7)
Cow (*Bos domesticus*)	1 (2.3)	0
Unidentified mammal (hair)	19 (44.2)	10 (25.6)
Unidentified bone	2 (4.7)	5 (12.8)

examination of regurgitated pellets found at roost sites also indicated that Bald Eagles wintering along the upper St. Lawrence River had a diverse diet, with several species each of fish, waterfowl and fur-bearing mammals being identified, as well as deer.

Selection of overwintering location may depend on many factors, including food availability. The frequent evidence of White-tailed Deer in eagle pellets suggests that this species makes an important contribution to their winter diet. It is possible that eagles winter in this area because of the ease and likelihood of locating deer carcasses on the ice, rather than easy access to aquatic prey as a result of the open water. However, the true contribution of deer to the total energy intake of the eagles is difficult to ascertain given the biases of pellet analysis. Pellets of raptors, which are typically regurgitated daily (Duke et al. 1976), are composed of the indigestible portions of their prey, including bones, hair, scales, feathers, teeth and chitin. Food which is highly digestible may not be represented in the pellets. The amount of indigestible material from a meal on a deer carcass would be greatly reduced once the hide had been torn through and exposed flesh was being eaten. Hair would largely be avoided at that point and eagles would pick flesh off the bones rather than consume them (Frenzel and Anthony 1989). Given this scenario, the contribution of deer to the diet may be underestimated through pellet analysis. Alternatively, with an intact deer carcass, much hair may initially be eaten with relatively little flesh being consumed, so that energy intake may actually be overestimated through pellet analysis (Mersmann et al. 1992). An accurate representation of the contribution of deer remains to the diet of Bald Eagles therefore, relies on the knowledge of whether the eagles fed on whole carcasses or on exposed flesh, which may only be determined through direct feeding observations.

Ewins and Andress (1995), through direct observations, also found deer to be an important component of the winter diet of eagles in the same area of the upper St. Lawrence River (see Table 2); much less so for populations wintering in other portions of the Great Lakes basin. Those authors suggested there was a bias towards observations of eagles feeding on deer carcasses, given their large size and high visibility (usually on the ice) of the prey item, which could cause an overestimation of the contribution of deer where they occurred. However, both techniques of diet analysis, direct observation and analysis of pellets, yielded very similar estimates of eagle consumption of deer, calculated over seven seasons of observations and two years of pellet analysis, albeit in different years (Table 2).

Common Mergansers occurred frequently in both 1996 and 1997, whereas Wood Ducks were only commonly identified in 1996; waterfowl jointly occurred in approximately half all pellet samples (Table 2). Although Wood Ducks rarely overwinter in the upper St. Lawrence River, they may remain until late November and return in early March (B. Andress, personal observation). As there is extensive duck hunting activity in the area, Bald Eagles may be consuming hunter-crippled birds unable to migrate. The contribution of waterfowl to eagle diets as assessed by direct visual observations was < 10% (Table 2). Ewins and Andress (1995) suggest this estimate may have been low, as waterfowl would have been captured at holes of open water, often away from convenient observation points; they are quite small and less obvious, and hence may have been missed. Despite the ability of raptors to digest bone and feathers (Glading et al. 1943; Duke et al. 1976), potentially biasing pellet analysis to underestimate the contribution of birds and small mammals, these dietary components appear to be well represented through this method of diet determination. Mersmann et al. (1992), however, found that medium sized fur-bearing mammalian prey could actually be over-represented in pellets because of difficulty in ridding the stomach and crop of short hairs, so that a single meal of an animal could contribute indigestible remains to more than one pellet.

Fish bones are apparently more completely digested by raptors than bones of other vertebrates (Todd et al. 1982), and it has been suggested that fish in the diet are severely underestimated by pellet analysis (Griffin et al. 1982; Todd et al. 1982; Kozie 1986; Bowerman 1993). Carp remains in particular occurred in pellets commonly in 1997, and accounted for the increase in the overall fish contribution

TABLE 2. Proportions of major food types in the winter diet of Bald Eagles in the Upper St. Lawrence River as determined by analysis of pellets collected in 1996 and 1997 and through direct feeding observations from 1987–1995.

Prey type	Number of pellets (%): This study 1996	Number of pellets (%): This study 1997	Number of observations (%): Ewins and Andress (1995)
Fish	5 (11.6)	11 (28.2)	59 (26.2)
Bird	17 (39.5)	22 (56.4)	14 (6.2)
Deer	31 (72.1)	26 (66.7)	139 (61.8)
Other Mammals	4 (9.3)	4 (10.2)	13 (5.8)

that year. It is interesting that indications of fish consumption by St. Lawrence River Bald Eagles as revealed by pellet analysis were similar to those found through direct observation of eagles, and both techniques, although not directly comparable, suggest that fish occurred in less than 30% of eagle meals (Table 2: Ewins and Andress 1995).

If the high frequency of deer remains in eagle regurgitant pellets truly indicates that deer constitute a large proportion of their winter diet relative to aquatic-based prey items, there may be implications for a reduced intake of persistent organochlorine contaminants. As terrestrial herbivores, deer are relatively low in organochlorine contamination, whereas fish and fish-eating birds in the Upper St. Lawrence and eastern Lake Ontario are still quite highly contaminated (Pekarik et al. 1998). For example, in 1997 the eggs of Herring Gulls (which are primarily a fish-eating species) from Strachan Island in the St Lawrence River contained 14 ppm PCB (wet weight), similar to levels in known contamination hotspot, Hamilton Harbour in western Lake Ontario, where the mean PCB concentration was 12.7 ppm. These levels are far above those in Bald Eagle eggs known to cause decreases in productivity (Kubiak and Best 1991). It is largely unknown where eagles wintering in this region breed, but a radio-tagged male in 1994 and a radio-tagged female in 1997 were tracked to their breeding grounds in central Quebec (latitude 49° N, longitude 74°W: P. Nye, NYSDEC, personal communication). Whatever the case, apparent reliance on deer carcasses in their diet suggests that that birds wintering in the upper St. Lawrence River area are not returning to their breeding grounds with a substantial burden of organochlorine contaminants accumulated during the winter months.

Acknowledgments

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Literature Cited

Adorjan, A. S., and **G. B. Kolenosky.** 1969. A manual for the identification of hairs of selected mammals. Research Report 90, Ontario Department of Lands and Forests. Toronto.

Bowerman, W. W., IV. 1991. Factors influencing breeding success of Bald Eagles in upper Michigan. M.A. thesis, Western Michigan University, Marquette.

Bowerman, W. W., IV. 1993. Regulation of Bald Eagle (*Haliaeetus leucocephalus*) productivity in the Great Lakes basin: an ecological and toxicological approach. Ph.D. dissertation, Michigan State University, East Lansing.

Bowerman, W. W., IV, D. A. Best, J. P. Giesy, T. J. Kubiak, and **J. G. Sikarskie.** 1994. The influence of environmental contaminants on Bald Eagle populations in the Laurentian Great Lakes, North America. Pages 703–709 *in* Raptor Conservation Today. World Working Group on Birds of Prey. *Edited by* B. U. Meyburg and R. D. Chancellor. The Pica Press. Buteo Books. Virginia.

Duke, G. E., O. A. Evanson, and **A. Jegers.** 1976. Meal to pellet intervals in 14 species of captive raptors. Comparative Biochemical Physiology 53A: 1–6.

Elliott, J. E., K. M. Langelier, A. M. Scheuhammer, P. H. Sinclair, and **P. E. Whitehead.** 1992. Incidence of lead poisoning in bald eagles and lead shot in waterfowl gizzards from British Columbia, 1988–1991. Canadian Wildlife Service Progress Notes number 200.

Ewins, P. J., and **R. A. Andress.** 1995. The diet of Bald Eagles, *Haliaeetus leucocephalus*, wintering in the lower Great Lakes basin, 1987–1995. Canadian Field-Naturalist 109: 418–425.

Frenzel, R. W., and **R. G. Anthony.** 1989. Relationship of diets and environmental contaminants in wintering Bald Eagles. Journal of Wildlife Management 53: 792–802.

Glading, B., D. F. Tillotson, and **D. M Selleck.** 1943. Raptor pellets as indicators of food habits. California Fish and Game 29: 92–121.

Griffin, C. R., T. S. Baskett, and **R. D. Sparrowe.** 1982. Ecology of Bald Eagles wintering near a waterfowl concentration. U.S. Fish and Wildlife Service Special Scientific Report, Wildlife, Number 247, Washington, D.C.

Grubb, T. G., W. W. Bowerman, and **P. H. Howey.** 1994. Tracking local and seasonal movements of wintering Bald Eagles *Haliaeetus leucocephalus* from Arizona and Michigan with satellite telemetry. Pages 346–358 *in* Raptor Conservation Today. World Working Group on Birds of Prey. *Edited by* B. U. Meyburg and R. K. Chancellor. The Pica Press, Buteo Books, Virginia.

Hunter, P., and **D. Baird.** 1995. The Bald Eagle in Ontario's Great Lakes basin. Bird Trends 4: 17–18. Environment Canada, Ottawa.

Kozie, K. D. 1986. Breeding and feeding ecology of Bald Eagles in the Apostle Islands National Lakeshore. M.Sc. thesis, University of Wisconsin Stevens Point, Wisconsin.

Kozie, K. D., and **R. K. Anderson.** 1991. Productivity, diet, and environmental contaminants in Bald Eagles nesting near the Wisconsin shoreline of Lake Superior. Archives of Environmental Contamination and Toxicology 20: 41–48.

Kubiak, T. J., and **D. A. Best.** 1991. Wildlife risks associated with passage of contaminated anadromous fish at federal energy regulatory commission licensed dams in Michigan. U.S. Fish and Wildlife Service Report of Contaminants Program. East Lansing, Michigan.

Lingle, G. R., and **G. L. Krapu.** 1986. Winter ecology of Bald Eagles in southcentral Nebraska. Prairie Naturalist 18: 65–78.

Marti, C. D. 1987. Raptor food habits studies. Pages 67–80 *in* Raptor management techniques manual. *Edited by* B. G. Pendleton, B. A. Milsap, K. W. Cline, and D. M. Bird. National Wildlife Federation Scientific Technical Series Number 10, Washington, D.C.

Mersmann, T. J., D. A. Buehler, J. D. Fraser, and **J. K. D. Seegar.** 1992. Assessing bias in studies of Bald Eagle food habits. Journal of Wildlife Management 56: 73–78.

Pekarik, C., D. V. Weseloh, G. C. Barrett, M. Simon, C. A. Bishop, and **K. E. Pettit.** 1998. An Atlas of Contaminants in the Eggs of Fish-Eating Colonial Birds of the Great Lakes (1993–1997). Volume II: Accounts by location. Technical Report Series Number 322. Canadian Wildlife Service, Ontario Region, Toronto.

Postupalsky, S. 1973. Toxic chemicals and declining Bald Eagles and Cormorants in Ontario. Canadian Wildlife Service (Pesticide Section) Manuscript Report Number 20.

Sabo, B. A., and **R. C. Laybourne.** 1994. Preparation of avian material recovered from pellets and as prey remains. Journal of Raptor Research 28: 192–193.

Todd, C. S., L. S. Young, R. B. Owen, Jr., and **F. J. Gramlich.** 1982. Food habits of bald eagles in Maine. Journal of Wildlife Management 46: 636–645.

Wiemeyer, S. N., T. G. Lamont, C. M. Bunck, C. R. Sindelar, F. J. Gramlich, J. D. Fraser, and **M. A. Byrd.** 1984. Organochlorine pesticide, polychlorinated-biphenyl, and mercury residues in Bald Eagle eggs — 1969–79 — and their relationships to shell thinning and reproduction. Archives of Environmental Contamination and Toxicology 13: 529–549.

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Influence of Prescribed Fire History on Habitat and Abundance of Passerine Birds in Northern Mixed-Grass Prairie

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To more effectively manage remaining native grasslands and declining populations of prairie passerine birds, linkages between disturbance regimes, vegetation, and bird abundance need to be more fully understood. Therefore, we examined bird-habitat relationships on mixed-grass prairie at Lostwood National Wildlife Refuge (NWR) in northwestern North Dakota, where prescribed fire has been used as a habitat management tool since the 1970s. We sampled bird abundance on upland prairie at 310 point count locations during 1993 and 1994 breeding seasons. We also measured vegetation structure and composition at each location. Complete fire histories were available for each point, with over 80% having been burned one to four times in the previous 15 years. Post-fire succession generally transformed vegetation structure from short, sparse, and grassy with few forbs and low litter immediately after fire, to increasing and moderate amounts of forbs, litter, and shrubs two to eight years postfire, to tall, dense, shrubby prairie with little forb, grass, or litter understory when fire was absent (>80 years). Most grassland birds (six of nine species examined) at Lostwood NWR were absent from prairie untreated with fire. Species richness and abundances of Baird's Sparrows (*Ammodramus bairdii*), Bobolinks (*Dolichonyx oryzivorus*), Grasshopper Sparrows (*A. savannarum*), Le Conte's Sparrows (*A. leconteii*), Sprague's Pipits (*Anthus spragueii*), and Western Meadowlarks (*Sturnella neglecta*) were positively related to an index of amount of fire, and these species were absent from unburned units. In contrast, Common Yellowthroats (*Geothlypis trichas*) and Clay-colored Sparrows (*Spizella pallida*) both reached highest abundance on unburned prairie. To provide maximum grassland bird diversity, managers of mesic, mixed-grass prairie generally should provide areas with short (2-4 year), moderate (5-7 year), and long (8-10 year, or more) fire return intervals. Because long-term rest may create habitat unfavorable for most species of grassland passerines in mesic, northern mixed prairie, periodic defoliations by disturbances such as fire should be considered essential to restore and maintain native biodiversity.

Key Words: Baird's Sparrow, *Ammodramus bairdii*, Sprague's Pipit, *Anthus spragueii*, grassland, habitat management, grassland birds, fire ecology, plant succession, mixed-grass prairie, North Dakota, Great Plains.

Grassland bird populations have been declining more precipitously in recent decades than those of any other group of North American birds (Droege and Sauer 1994). These population declines parallel vast reductions in native prairie habitats that grassland birds depend on. Native grasslands throughout North America have been severely degraded, fragmented, and reduced by cumulative effects of overgrazing, fire suppression, invasion by exotic plants, and conversion to cropland (review in Samson and Knopf 1996). For example, estimated declines in extent of tallgrass prairie range from 83 to 99% and exceed those reported for any other North American ecosystem, including old-growth forest and temperate rainforest (Samson and Knopf 1994). Mixed-grass prairie has declined by 72 to 99% from Manitoba to Nebraska.

Individual bird species do not respond alike to common grassland management practices, with various species preferring specific habitat conditions along a continuum of prairie succession (reviews in Kirsch et al. 1978; Ryan 1990; Dobkin 1992). Species that prefer vegetation communities promoted by human activities such as annual mowing or grazing, and fire suppression generally have benefited in recent years. In contrast, those species requiring more natural disturbance regimes (i.e., periodic fire and grazing) have suffered the worst declines (Dobkin 1992; Knopf 1994, 1996). For example, 14 of 19 widespread grassland species and six of nine endemic species are declining (Knopf 1996).

Remaining tracts of prairie thus become increasingly valuable for native species, and their proper management critical for maintaining native biodiversity. To manage these resources effectively, we must understand linkages between disturbance regimes, vegetation, and bird communities; yet relatively few studies have addressed effects of fire on prairie passerines. Those conducted typically included only a single burn and control (Huber and Steuter 1984; Pylypec 1991), or followed responses only one to three years postfire (Forde et al. 1984; Herkert 1994). These studies documented general declines in species diversity and abundance immediately following fire, and variable population increases of some species one to three years postfire. Assessments of fire effects that consider only immediate post-fire response ignore a large portion of the natural disturbance cycle on the Great Plains. Only one long-term study of fire effects on birds has been completed in mixed-grass prairie (Johnson 1997).

Our goal was to document longer-term effects of fire by examining multiple, independent burns done over an extended period (15 years) in mixed-grass prairie. The objective of this study was to quantify relationships between fire history and bird abundance and species richness in northern mixed-grass prairie. We also assessed vegetation structure and composition as it related to post-fire succession.

Study Area

Lostwood National Wildlife Refuge (NWR) covers 109 km^2 of rolling to hilly, mixed-grass prairie in northwestern North Dakota (48°37′N; 102°27′W). It lies within the Missouri Coteau (Bluemle 1980), a strip of dead-ice, glacial moraine characterized by knob-and-kettle topography (685–747 m elevation). Large tracts of grassland are interspersed with ≈4000 wetland basins and ≈500 clumps of Quaking Aspen (*Populus tremuloides*). Major vegetation is a needle-grass-wheatgrass (*Stipa* spp.- *Agropyron* spp.) association (Coupland 1950), and habitat composition is 55% native prairie, 21% previously-cropped prairie (revegetated with tame and native prairie plants), 20% wetland, 2% trees, and 2% tall shrubs (Murphy 1993). Climate is semi-arid and mean annual precipitation (1936–1989) on the refuge is 42 cm, with most (>75%) falling as rain between April and September.

Before European settlement in the early 1900s, the landscape of Lostwood NWR was a treeless expanse of mixed-grass prairie, maintained in a shorter grass, or even barren state by frequent fire and Bison (*Bison bison*) impacts (Murphy 1993). The region likely supported a 5- to 10-year fire-return interval (Wright and Bailey 1982: 81; Murphy 1993, Bragg 1995). Although some of present-day Lostwood NWR was tilled and farmed during the early 1900s, most (70%) upland areas remained unbroken and were either rested or lightly grazed season-long by livestock during the 1930s–1970s. With settlement came suppression of wildfires, and a concomitant loss of early successional, herbaceous vegetation. Western Snowberry (*Symphoricarpos occidentalis*), aspen, and exotic grasses (Kentucky Bluegrass [*Poa pratensis*], Smooth Brome [*Bromus inermis*], and Quack Grass [*Agropyron repens*]) proliferated and now dominate the mixed-grass community of Lostwood NWR.

Since the 1970s, the U.S. Fish and Wildlife Service (USFWS) has used prescribed fire to reduce woody vegetation and restore a more natural diversity of successional stages to Lostwood NWR. The refuge was divided into ≈20 prescribed burn units (range = 5–2265 ha; $\bar{x}$ = 310 ha). During 1978–1993, 63 burns were conducted and 5–35% of the refuge was burned annually. Decisions on when to burn a given unit were based on land management objectives, thus, fire treatments were not randomly assigned to burn units. Most burns (75%) were conducted in summer (mid-July through August) and the remainder in late spring (late April through early May). Burns typically were done in 10–30 km/h wind, 20–40% relative humidity, and 10–30°C, and generally removed 80–95% of above-ground vegetation.

Methods

Study Design and Plot Selection

We measured bird abundance and vegetation characteristics on 160 (1993) and 150 (1994) sample points distributed over nine independent burn units. We selected sampling points from a grid of potential points that encompassed the study area. The sampling scheme was systematic in 1993, but was randomized in 1994 to meet sampling assumptions for statistical testing. Points were > 250 m apart to provide statistical independence in terms of birds and vegetation (Hutto et al. 1986; Ralph et al. 1993), and were randomly selected from potential points that met the following criteria: (1) located in "upland prairie" as delineated by the National Wetland Inventory map of cover types of Lostwood NWR (USFWS, unpublished report), (2) > 200 m from any aspen clump, (3) > 50 m from roads or firebreaks, and (4) ungrazed by livestock for > 10 years. In 1994, we reduced the buffer from aspen to 100 m based on 1993 sampling observations, and added a 50-m buffer from any seasonally-flooded wetland zone because of high water levels. Points within a given burn unit were not independent in terms of fire history, thus data within a unit were averaged for all statistical analyses.

Fire History

Fire history for each point count location was compiled from Lostwood NWR maps and narratives (Table 1). Fire history was described as: (1) number of years since the point was burned (0.5–8.0 or >80 years), and (2) number of times the point was burned in previous 15 years (0–4 times). Areas burned recently tended to have been burned many times. This could potentially confound results, making it difficult to discern relative impacts of each variable. Both variables played a role in defining fire history, thus we combined them using an index to describe the amount of fire an area had experienced:

Fire Index (FI) = Number of Burns/Years Since Last Fire

Using this formula, sampled burn units were scaled along a gradient from 0.0 (no fire) to 6.0 (many burns, the last recently) (Table 1). Although there may be problems extrapolating this index to all fire histories, it appeared to aptly depict the nine

TABLE 1. Fire history* on prescribed burn units sampled at Lostwood National Wildlife Refuge, North Dakota.

		1993				1994			
Burn name	Size (ha)	Sample points	Number of burns	YSF[a]	Fire index[b]	Sample points	Number of burns	YSF[a]	Fire index[b]
Unburned - West	526	17	0	>80	0.00	12	0	>80	0.00
Unburned - South Central Core	445	15	0	>80	0.00	18	0	>80	0.00
Green Needle	398	11	1	6	0.17	6	1	7	0.14
Wilderness	2265	34	2	5	0.40	25	2	6	0.33
North Dead Dog Slough	89	5	4	7	0.57	9	4	8	0.50
Kruse	645	23	2	3	0.67	20	3	0.5	6.00
Aspen	518	10	2	0.5	4.00	20	2	2	1.00
Thompson Lake	372	14	4	1	4.00	20	4	2	2.00
Teal Slough	494	28	4	1	4.00	20	4	2	2.00

*source: USFWS (unpublished data)
[a]YSF = Years since last fire.
[b]Fire Index = number of burns/years since last fire. The index varies from 0.0, no fire experienced in >80 years, to 6.0, several fires with the last less than one year previous.

burn units sampled in this study along a plausible gradient of amount of fire experienced.

Bird Abundance Sampling

We conducted three bird counts at each sample point during 29 May–7 July 1993 and 26 May–24 June 1994. Bird abundance was estimated using 50-m fixed-radius point counts (Hutto et al. 1986) in 1993, and point counts with five distance categories in 1994 (Buckland et al. 1993; Madden 1996). During each count, an observer stood at a point for 10 minutes and recorded all birds seen or heard, and the distance category to each bird when first detected. To minimize observer differences and maximize accuracy of measurements, we (1) spent two weeks prior to data collection practicing bird identification, point count techniques, and distance measurements, especially for birds detected aurally; (2) observed each point before approaching it to record distances from the point to birds that might be disturbed by our approach; and (3) used flags marking distance category boundaries at each point to ensure accurate distance estimation. When assignment to a distance category was uncertain, we measured the distance to a bird's location by pacing after the count was completed. We conducted counts one-half hour before sunrise until approximately 09:00 CST only on mornings when weather conditions did not impede detection of birds (i.e., no rain, fog, or wind >15 km/h). Observers and the order in which points were visited were rotated to minimize sampling bias. Although all bird species were recorded, only passerine species were well-represented on point counts and included in the final data set.

We calculated the mean number of singing males of each species per 50-m (1993) or 75-m (1994) radius point count (average of three visits). (A 75-m, rather than 50-m, radius cut-off was used for 1994 data to increase the number of birds sampled [Rotella et al. 1997]). Abundance of Brown-headed Cowbirds (scientific names for bird species are listed in Table 3) was calculated differently: we divided total number of cowbirds seen or heard at a count by two, for comparability with singing male data for other species. Total passerine abundance was simply the total number of singing male passerines at each point averaged over three visits. We calculated species richness for singing males using the total number of species observed within 50 m (1993) or 75 m (1994) of each point during three visits (i.e., cumulative richness). To avoid bias due to differences in numbers of points sampled in each burn unit, we chose a random subsample of five (1993) or six (1994) points (i.e., lowest common denominator) from each burn unit to calculate richness.

Vegetation Sampling

Vegetation structure and general composition were measured at each bird sampling point during 28 June–7 August 1993 and 28 June–28 July 1994. Twenty subsample points were located along two transects within each fixed-radius bird plot. Both transects were positioned on the same random compass bearing (i.e., parallel), each a different random number of paces from plot center.

At each subsample point, we estimated visual obstruction from a height of 1 m and a distance of 4 m using a Robel pole (Robel et al. 1970). Litter depth was measured directly (cm) by lowering a 6-mm diameter rod vertically into the litter layer 30 cm east of the Robel pole. Dead vegetation from previous years that was standing but no longer vertical was considered litter where it formed a mat-like layer, roughly continuous with the ground. Using the same rod, we counted the total number of "hits" or contacts of vegetation on the rod in each dm height interval (Wiens 1969). Each hit was recorded as either live (current year's growth) or dead (previous years' growth). Total number of hits represented vertical density. We also calculated the percentage of total hits represented by live vegetation. Percentage areal cover of shrubs, forbs, and grasses was visually estimated (Daubenmire 1959) within a 1-m diameter circular frame centered on each Robel pole. Finally, each subsample was assigned to one of nine general plant species associations: native grass, Kentucky Bluegrass, native grass/Kentucky Bluegrass, broad-leaved exotic grass, shrub, shrub/broad-leaved exotic grass, shrub/Kentucky Bluegrass, shrub/native grass, and wetland (Madden 1996).

For each vegetation structure variable, we calculated the mean and coefficient of variation (CV) for the 20 subsamples near each point. Coefficient of variation measures horizontal "patchiness" or heterogeneity of a particular vegetation attribute (Roth 1976). Plant associations were expressed as the mean frequency of a given association in the 20 subsamples. Fourteen vegetation structure variables and nine plant associations were considered.

Data Analyses

Data for 1993 and 1994 were analyzed separately because several bird species differed significantly in abundance between the two breeding seasons, and weather differences were also extreme. Only bird species detected at >10% of points were included in statistical analyses. We used Kruskal-Wallis 1-way Analysis of Variance (SAS Institute 1988) to test hypotheses that there were no differences in vegetation or bird abundance among categories of burns. Burn categories were: (1) Years since last fire (1–3, 5–7, or >80 years in 1993 and 2, 6–8, or >80 years in 1994), and (2) Number of burns in last 15 years (0, 1–2, or 4). Results of these analyses are presented fully by Madden (1996).

Because it was difficult to tease out relative impacts of the two variables of fire history, we then used simple linear regression (Chatterjee and Price 1991) to quantify relationships between vegetation or birds and the fire index (which combined the two fire variables). Regressions were performed on means of vegetation attributes or bird abundances for each of the burn units rated by fire index. The smaller radius (50–m) point counts used in 1993 yielded low numbers of bird observations, and resulting data were primarily zeros for most species. Too many zero records in the data violated the assumptions of normality and constant variance required for use of linear regression models, and we were unsuccessful in our attempts to normalize data and stabilize variances using transformations. Therefore, only 1994 bird data were used in this part of the analysis. Several vegetation variables also did not meet regression assumptions and were not analyzed further: frequency of shrub/exotic grasses and shrub/Kentucky bluegrass in 1993, and CV litter depth and frequency of shrub in both years. Burn units that had not had a full growing season of vegetation recovery (i.e., years since last fire = 0.5) were omitted from regression analyses. Burned during the previous August, these areas generally had extreme vegetation and bird responses, unreflective of the longer-term fire effects we sought to document. Areas burned in the spring previous (i.e., years since last fire = 1.0), having had one full growing season for vegetation to recover, were included.

Because many variables of vegetation structure were correlated, we also used principal components analysis (SAS Institute 1988) to identify major gradients in vegetation structure. Although most ecological data violate some fundamental assumptions of principal components analysis (e.g., normality) for purposes of hypothesis testing, the technique is useful for synthesizing and describing patterns in data (Gauch 1982: 143). We plotted 1994 sample points by fire history on a plot of the first two principal components to describe each burn unit's location in principal component vegetation space. We then plotted a 95% confidence ellipse (Wilkinson 1990) based on the mean for each fire interval and superimposed the ellipses onto a single graph for comparative purposes.

Results

Vegetation and Fire

Relationships between individual vegetation variables and the fire index, as measured by slope of regression line, were similar both years, even if not significant ($P < 0.05$) in both (Table 2). Grass cover increased with amount of fire, whereas shrub cover, CV grass cover, and vegetation density decreased. Variances in vegetation variables (CVs), which reflected structural heterogeneity, generally decreased with amount of fire as did litter depth. Native grass/Kentucky Bluegrass and broad-leaved, exotic grasses increased in frequency with amount of fire.

Four principal components had eigenvalues greater than 1.0, accounting for 81% and 83% of the variation in vegetation structure in 1993 and 1994, respectively. Only the first two components are examined here because the third and fourth components explained relatively little of the variation, and also because more than two dimensions are difficult to visualize. Eigenvectors and gradients were remarkably similar for these two components between years. The first axis (PC1) accounted for 39% and 38% of the variation in 1993 and 1994, and represented a gradient from short, sparse, grass-dominated vegetation to tall, dense, shrub-dominated vegetation (Figure 1). The second axis (PC2) accounted for 18% and 20% of the variation in 1993 and 1994, and represented a gradient from deep litter and forb-dominated vegetation to mostly live vegetation with few forbs and low litter (Figure 1).

TABLE 2. Relationships between vegetation variables and fire index (see text for explanation of fire index) based on simple linear regression (n = 8 burn units). Only results for vegetation variables with significant ($P < 0.05$) regression relationships in at least one year are reported.

Vegetation variable	1993 R^2	1993 P	1994 R^2	1994 P	Response to fire[a]
Shrub cover	0.56	0.03	0.53	0.04	-
Grass cover	0.86	0.00	0.83	<0.01	+
CV forb cover	0.11	0.42	0.53	0.04	-
CV grass cover	0.49	0.05	0.55	0.04	-
CV visual obstruction	0.22	0.24	0.68	0.01	-
Litter depth	0.90	0.00	0.15	0.35	-
Density (# hits)	0.65	0.02	0.66	0.01	-
% live vegetation	0.90	0.00	0.38	0.10	+
CV % live vegetation	0.67	0.01	0.26	0.20	-
Kentucky Bluegrass/native grass	0.48	0.06	0.60	<0.01	+
Broad-leaved exotic grass	0.73	0.01	0.34	0.13	+
Shrub/Kentucky Bluegrass	[b]	[b]	0.50	0.05	-
Shrub/native grass	0.50	0.05	0.40	0.09	-

[a]Fire response based on slope (+ or -) of regression line.
[b]Variable did not meet regression assumptions in 1993.

Confidence ellipses for 1994 burn units in PC vegetation space indicated that the unit with the most distinct vegetation was the area burned several times, the last occurring the previous August (i.e., about 0.5 years earlier) (Figure 1). Its confidence ellipse was located at the extreme negative end of PC1, defined by short, sparse grassy cover, and the extreme positive end of PC2, indicating low litter and few forbs. An area burned twice, the last being two years previous, was also distinct, but closer to the graph origin (i.e., "average" vegetation characteristics). This area fell to the short, sparse, grassy (negative) side of PC1 and was centered on zero on PC2, indicating moderate litter and forbs.

Areas last burned two years previous, but four times in the last 15 years, fell wholly in the short and sparse, litter-, grass-, and forb-dominated quadrat of the graph and overlapped slightly with an area burned one time, seven years previous. This one-burn area fell mostly in the quadrat defined by tall, dense, shrub- and forb-dominated vegetation with much litter. Complete overlap with this ellipse occurred for areas last burned six years ago (two times) and eight years ago (four times). This illustrates great similarity in vegetation structure six to eight years postfire. The confidence ellipse for unburned units overlapped no others and was located on the tall, dense, shrub-dominated side of PC1, and toward the low litter, few forbs side of PC2.

Birds and Fire

We observed 19 and 24 passerine bird species on 50- and 75-m radius plots in 1993 and 1994, respectively (Table 3). Nine and ten species were detected at > 10% of points in 1993 and 1994. Savannah Sparrows and Clay-colored Sparrows were by far the most frequently encountered species; both occurred more than twice as frequently as other species during both years. Several species were completely absent from unburned (> 80 years) units both years (Tables 4 and 5). Baird's Sparrows, Grasshopper Sparrows, Le Conte's Sparrows, Sprague's Pipits, and Western Meadowlarks were never detected during three visits to each of 62 point count locations in unburned units. Bobolinks also were absent from unburned areas except for two detections of a singing male at one point in 1993. In contrast, none of ten species examined was completely absent from units treated with fire.

Abundances of eight bird species and species richness had significant ($P < 0.05$) long-term relationships with amount of fire in 1994 (Table 6, Figure 2). Six species and species richness responded positively to amount of fire: Baird's Sparrow, Bobolink, Grasshopper Sparrow, Le Conte's Sparrow, Sprague's Pipit, and Western Meadowlark. These species reached highest abundance in units with a fire index rating of 2.0 (i.e., burned four times, the last being two years prior). Two species responded negatively to fire: Clay-colored Sparrow and Common Yellowthroat. Both were most abundant in units with a fire index of 0.0 (i.e., unburned in >80 years). Savannah Sparrow, Brown-headed Cowbird, and total passerine abundance did not respond significantly to amount of fire.

Discussion

Vegetation and Fire

In our study, repeated fire reduced shrub cover, litter build-up, and vegetation height and density, but increased grass cover and percentage of live vegetation on mixed-grass prairie. Fire decreased horizon-

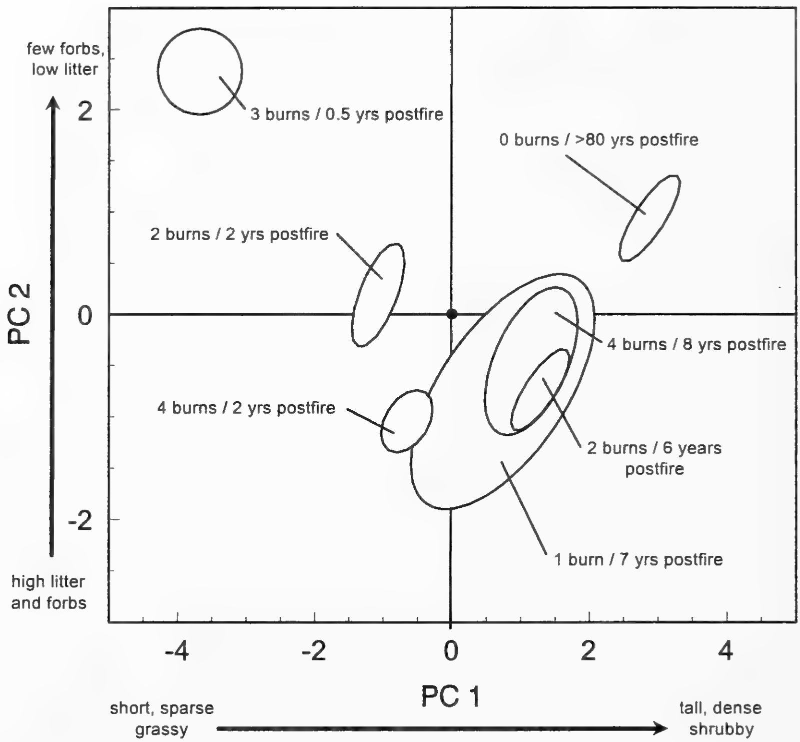

FIGURE 1. Composite confidence ellipses for areas with different burn histories in 1994. Ellipses represent 95% confidence intervals around the mean position of sample points with similar burn histories, located with reference to Principal Components 1 and 2.

tal patchiness of grasses, forbs, live vegetation, and visual obstruction, and increased litter patchiness. These results are consistent with previous findings concerning the role of fire in maintaining mixed-grass prairie vegetation. Annual die-offs of grass and the resulting litter build-ups necessitate some type of defoliation in these semi-arid environments where plant decomposition is otherwise slow (Kucera 1981; Wright and Bailey 1982; Bragg 1995). Fire reduces vegetation biomass and litter and increases growth and reproduction of native vegetation (Kucera 1981; Wright and Bailey 1982). Vegetation in burned tall-grass prairie generally begins growing earlier, matures earlier, and produces more flowering stalks, especially of native plants (Ehrenreich 1959). This enhanced growth is attributed to reduced litter, warmer soil temperatures, increased light for emerging shoots, and greater nutrient availability after burning (Ehrenreich 1959; Daubenmire 1968; Kucera 1981).

Exotic and native grasses alike increased with prescribed fire at Lostwood NWR. In northern mixed-grass prairie, fire is sometimes considered for reducing exotic grasses such as Smooth Brome (Romo and Grilz 1990), but our data from multiple burns over 15 years do not support this. Refuge personnel concur with our findings and report that Smooth Brome increased in all management units of Lostwood NWR during the 1970s–1990s, regardless of treatment history (K. A. Smith, personal communication). Fire impacts on individual plant species depend largely on treatment timing in relation to plant phenology (Higgins et al. 1989). Prescribed burns on any given management unit at Lostwood NWR were conducted from spring to late summer, obscuring effects of the timing of burns on changes in exotic grass coverage.

Suppression of woody vegetation is a more obvious and well-documented effect of fire on grassland habitats (review in Higgins et al. 1989). High coverages and frequencies of shrubs were successfully reduced with fire at Lostwood NWR.

During post-fire succession on mixed-grass prairie at Lostwood NWR, vegetation structure was generally transformed from short, sparse, and grassy with few forbs and low litter immediately after fire, to increasing and moderate amounts of forbs, litter, and shrubs two to eight years postfire, to tall, dense, shrubby prairie with little forb, grass, or litter understory when fire was absent (> 80 years). Although relatively low litter seems surprising for unburned units, parts of these units were covered by decadent snowberry shrub with little or no understory, and any existing understory was usually lush, green growth of smooth brome. These extensive shrub stands likely account for the low litter readings in the longest-idled burn units.

The similarity of 2 to 8 year postfire vegetation structure to "average" characteristics (i.e. closest to origin on graph; see Figure 1), and the more extreme locations of 0.5-year and >80-year post-fire vegetation near the ends of the vegetation gradients is consistent with the estimated historic fire return interval of 5–10 years in mixed-grass prairie.

Birds and Fire

Most grassland birds (six of nine species examined) at Lostwood NWR were absent from mixed prairie untreated with fire for long periods. Abundances of Baird's Sparrows, Bobolinks, Grasshopper Sparrows, Le Conte's Sparrows, Sprague's Pipits, and Western Meadowlarks were positively related to amount of fire, and these species were absent from unburned units. Brown-headed Cowbirds and Savannah Sparrows showed inconclusive responses to fire. Savannah Sparrow abundance apparently is more associated with intermediate stages of post-fire succession (Madden 1996), and Brown-headed Cowbirds exploit a wide variety of habitats (Lowther 1993). Clay-colored Sparrows and Common Yellowthroats showed consistent, distinctly negative reactions to fire, which was not surprising, given both species are commonly associated with shrubby habitats.

Most short-term studies of fire effects simply point out that, for many bird species, abundance is depressed for one to several years postfire and then recovers (Forde et al. 1984; Huber and Steuter 1984; Pylypec 1991). Our data go a step further and illustrate that, in the longer term, most grassland species were absent from mesic prairie untreated with fire for long periods. This was also suggested by a study of shrubby versus shrubless prairie on the Missouri Coteau in south-central North Dakota (Arnold and Higgins 1986), where many true grassland species were absent (Baird's Sparrow, Savannah Sparrow) or reduced (Grasshopper Sparrow, Bobolink) on shrubby prairie such as that associated with a lack of fire.

Trends in species abundance were similar in another fire-effects study on the Missouri Coteau in North Dakota (Johnson 1997), with Bobolinks, Western Meadowlarks, and Grasshopper, Baird's, and Savannah Sparrows most common 2–5 years postfire, and declining after about five years postfire.

TABLE 3. Passerine bird species (singing males) detected during point counts, 1993 and 1994, Lostwood National Wildlife Refuge, North Dakota.

		% occurrence[a]	
Bird species	Scientific name	1993 (n = 160)	1994 (n = 150)
Eastern Kingbird	*Tyrannus tyrannus*	8.8	3.3
Horned Lark	*Eremophila alpestris*	0.6	1.3
House Wren	*Troglodytes aedon*	–	0.7
Sedge Wren	*Cistothorus platensis*	–	3.3
Marsh Wren	*Cistothorus palustris*	–	0.7
Gray Catbird	*Dumetella carolinensis*	0.6	–
Sprague's Pipit	*Anthus spragueii*	10.6	12.0
Yellow Warbler	*Dendroica petechia*	0.6	1.3
Common Yellowthroat	*Geothlypis trichas*	18.8	24.7
Clay-colored Sparrow	*Spizella pallida*	66.3	92.0
Vesper Sparrow	*Pooecetes gramineus*	6.3	8.0
Savannah Sparrow	*Passerculus sandwichensis*	63.8	92.7
Baird's Sparrow	*Ammodramus bairdii*	16.9	35.3
Grasshopper Sparrow	*Ammodramus savannarum*	20.6	41.3
Le Conte's Sparrow	*Ammodramus leconteii*	1.3	12.0
Nelson's Sharp-tailed Sparrow	*Ammodramus nelsoni*	–	2.7
Song Sparrow	*Melospiza melodia*	0.6	1.3
Chestnut-collared Longspur	*Calcarius ornatus*	0.6	0.7
Bobolink	*Dolichonyx oryzivorus*	27.5	44.0
Red-winged Blackbird	*Agelaius phoeniceus*	0.6	2.0
Western Meadowlark	*Sturnella neglecta*	13.1	18.0
Brewer's Blackbird	*Euphagus cyanocephalus*	2.0	2.0
Brown-headed Cowbird	*Molothrus ater*	20.0	21.3
American Goldfinch	*Carduelis tristis*	–	0.7

[a]Percentage of 50-m (1993) or 75-m (1994) radius points at which the species was detected (within the given radius).

TABLE 4. Bird species abundance and standard error (SE) in relation to years since last fire, Lostwood National Wildlife Refuge, 1993. Abundance is mean number of singing males per 50-m radius point count.

	Years since last fire						
	< 1 (*n*=10)[a]	1 (*n*=42)	3 (*n*=23)	5 (*n*=34)	6 (*n*=11)	7 (*n*=5)	> 80 (*n*=32)
Bird species	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Baird's Sparrow	0.00 (0.00)	0.13 (0.03)	0.13 (0.06)	0.11 (0.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Brown-headed Cowbird	0.27 (0.20)	0.14 (0.04)	0.08 (0.03)	0.10 (0.05)	0.00 (0.00)	0.00 (0.00)	0.03 (0.02)
Bobolink	0.00 (0.00)	0.48 (0.06)	0.07 (0.03)	0.05 (0.02)	0.06 (0.04)	0.13 (0.13)	0.04 (0.04)
Clay-colored Sparrow	0.33 (0.12)	0.25 (0.06)	0.34 (0.07)	0.53 (0.09)	0.61 (0.12)	0.27 (0.12)	0.57 (0.08)
Common Yellowthroat	0.00 (0.00)	0.02 (0.01)	0.00 (0.00)	0.05 (0.02)	0.03 (0.03)	0.20 (0.13)	0.24 (0.04)
Grasshopper Sparrow	0.00 (0.00)	0.17 (0.04)	0.30 (0.08)	0.06 (0.02)	0.03 (0.03)	0.07 (0.07)	0.00 (0.00)
Savannah Sparrow	0.17 (0.07)	0.32 (0.05)	0.57 (0.09)	0.32 (0.06)	0.79 (0.09)	0.73 (0.12)	0.25 (0.06)
Sprague's Pipit	0.00 (0.00)	0.08 (0.03)	0.10 (0.04)	0.02 (0.01)	0.03 (0.03)	0.20 (0.13)	0.00 (0.00)
Western Meadowlark	0.00 (0.00)	0.09 (0.03)	0.10 (0.04)	0.07 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
All passerines	0.97 (0.29)	1.82 (0.12)	1.73 (0.16)	1.35 (0.14)	1.61 (0.15)	1.67 (0.21)	1.22 (0.14)
Species richness	2.10 (0.31)	3.55 (0.19)	3.04 (0.26)	2.59 (0.20)	2.55 (0.25)	3.00 (0.32)	2.25 (0.20)

[a]*n* = number of point counts

In contrast to our study, however, none of these species was completely absent from the unburned control plot. Johnson's control plot had been idle for 11 years when his study was initiated, but had been grazed for 55 years prior to that. The two unburned plots in our study were likely in a more degraded grassland condition, as one had been completely idle (no burning or grazing) for >80 years, and the other had received only light season-long grazing until 16 years before this study. These differences between studies highlight the need for grassland managers to consider site-specific information when determining treatment needs, as well as the need for research replication across a range of conditions and grassland types.

Total species richness at Lostwood NWR was generally highest in areas experiencing periodic, frequent fire and lowest in unburned areas. Other studies of grassland passerines have shown species richness highest in idle or shrubby, late successional stages associated with lack of fire (Renken 1983; Arnold and Higgins 1986; Zimmerman 1992). These studies, however, included some trees, shrub thickets, and/or wetlands in plots, which inflated total species richness by adding non-prairie species associated with woody habitats. Because we limited our plots to upland prairie and avoided aspen groves and wetlands, we exclusively sampled grassland habitats, and thus mainly grassland bird species. Had we included aspen groves, common on unburned prairie at Lostwood NWR, total species richness would have been highest on unburned prairie due to presence of many woodland bird species. For grassland managers charged with maintaining a native bird community, emphasis on woody, later successional stages simply because they support greater avian

TABLE 5. Bird species abundance and standard error (SE) in relation to years since last fire, Lostwood National Wildlife Refuge, 1994. Abundance is mean number of singing males per 75-m radius point count.

	Years since last fire					
	<1 (*n*=20)[a]	2 (*n*=60)	6 (*n*=25)	7 (*n*=6)	8 (*n*=9)	>80 (*n*=30)
Bird species	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Baird's Sparrow	0.30 (0.10)	0.37 (0.06)	0.09 (0.04)	0.06 (0.06)	0.07 (0.05)	0.00 (0.00)
Brown-headed Cowbird	0.08 (0.05)	0.09 (0.02)	0.21 (0.07)	0.00 (0.00)	0.00 (0.00)	0.02 (0.01)
Bobolink	0.52 (0.09)	0.41 (0.06)	0.16 (0.06)	0.06 (0.06)	0.15 (0.11)	0.00 (0.00)
Clay-colored Sparrow	0.68 (0.14)	0.86 (0.08)	1.53 (0.17)	1.50 (0.17)	1.22 (0.33)	2.25 (0.15)
Common Yellowthroat	0.02 (0.02)	0.03 (0.02)	0.08 (0.04)	0.22 (0.14)	0.22 (0.08)	0.39 (0.06)
Grasshopper Sparrow	0.20 (0.06)	0.44 (0.06)	0.29 (0.06)	0.50 (0.11)	0.00 (0.00)	0.00 (0.00)
Le Conte's Sparrow	0.00 (0.00)	0.10 (0.03)	0.05 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Savannah Sparrow	0.93 (0.16)	0.99 (0.08)	1.27 (0.13)	1.61 (0.38)	1.52 (0.19)	0.91 (0.10)
Sprague's Pipit	0.02 (0.02)	0.10 (0.03)	0.01 (0.01)	0.06 (0.06)	0.00 (0.00)	0.00 (0.00)
Western Meadowlark	0.07 (0.04)	0.11 (0.02)	0.11 (0.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
All passerines	2.93 (0.28)	3.61 (0.17)	4.01 (0.24)	4.00 (0.56)	3.26 (0.32)	3.71 (0.22)
Species richness	4.10 (0.23)	4.98 (0.21)	4.48 (0.31)	3.67 (0.49)	3.22 (0.28)	3.03 (0.18)

[a]n = number of point counts

TABLE 6. Relationships between bird abundance and amount of fire (1994) based on linear regressions of abundance on the fire index ($n = 8$). Fire index is explained in the text.

Bird species	R^2	P	Response to fire[a]
Baird's Sparrow	0.79	<0.01	+
Bobolink	0.97	<0.01	+
Grasshopper Sparrow	0.49	0.05	+
Le Conte's Sparrow	0.79	<0.01	+
Sprague's Pipit	0.65	0.02	+
Western Meadowlark	0.64	0.02	+
Species richness	0.75	0.01	+
Clay-colored Sparrow	0.74	0.01	–
Common Yellowthroat	0.67	0.01	–
Savannah Sparrow	0.09	0.48	NS
Brown-headed Cowbird	0.18	0.30	NS
All passerines[b]	0.01	0.84	NS

[a]Response to fire based on slope (+ or -) of regression line.
[b]Total number of singing male passerines/point.

diversity may be inappropriate (Knopf and Samson 1994; Johnson 1996). In strictly grassland habitats, our data suggest that mesic, mixed-grass prairie treated with some type of periodic disturbance such as fire will support maximum species richness of grassland birds.

Fire History and Management

Fire has played a major role in maintaining Great Plains grasslands (review in Higgins 1986). But, without trees to carry records of burning in fire scars, it is difficult to estimate pre-settlement frequencies of grassland fires. Extrapolating from fire histories in grasslands under pine forests, Wright and Bailey (1982: 81) estimated a 5- to 10-year fire frequency for North American grasslands. Fire probably occurred, on average, every six years in northern mixed prairie, but up to every 25 years in the dry, western part of the mixed prairie, based on rates of fuel accumulation and woody plant invasion (Bragg 1995). This distinction between dry and mesic mixed prairie is important, because fire effects on vegetation and birds vary with moisture conditions (Higgins et al. 1989; Wright and Bailey 1982). In general, grasslands receiving more moisture have higher productivity and thus are more fire-dependent (Kucera 1981). Mixed-grass prairie of the Dakotas, including Lostwood NWR, generally is more mesic than that of Saskatchewan, Alberta, and Montana (Wright and Bailey 1982), and thus has more rapid accumulation of residual vegetation and a correspondingly higher fire frequency. Thus, a fire frequency that maximizes plant and bird diversity in mesic mixed prairie could be negative in dry mixed prairie.

Results of fire effects are further complicated because prescribed burns at Lostwood NWR were not merely "maintenance" burns on healthy mixed-grass prairie, but treatments to rectify more than 80 years of unnatural fire suppression and shrub accumulation (renovation burns). Renovation burns in areas of dense shrub build-up are characteristically different (e.g., hotter) than burns in herbaceous prairie. Most of Lostwood NWR's prairie remains less than pristine, and conclusions about bird and vegetation response to fire must consider this. But, because many remaining grasslands (especially on public land) have management histories similar to those of Lostwood NWR, our results can be used to anticipate outcomes as fire is restored to these systems.

Pre- and Post-Settlement Endemic Bird Populations

After receiving a series of renovation burns, native prairie at Lostwood NWR probably supports a breeding passerine community roughly similar to that of pre-settlement prairie. High numbers of endemic prairie species such as Baird's Sparrows and Sprague's Pipits in these repeatedly-burned areas are consistent with pre-settlement descriptions by Coues (1878). As he traveled near present-day Lostwood NWR in 1873, Coues remarked repeatedly on the "trio of the commonest birds" encountered: Baird's Sparrows, Sprague's Pipits, and Chestnut-collared Longspurs. Baird's Sparrows outnumbered all other birds together in some areas, and Sprague's Pipits were sometimes "...so numerous that the air seemed full of them..." (Coues 1878: 560). After less than 100 years of settlement and agricultural development, Baird's Sparrows and Sprague's Pipits had declined to the point that they were no longer among even the 15 most common birds in North Dakota (Stewart and Kantrud 1972). Population declines in these species have paralleled large reductions in extent and quality of native prairie habitats (see Goossen et al. 1993; Samson and Knopf 1996).

The third species of Coues' "commonest trio," Chestnut-collared Longspurs, were not among the common bird species during this study: only two breeding males were seen (both on units one-year

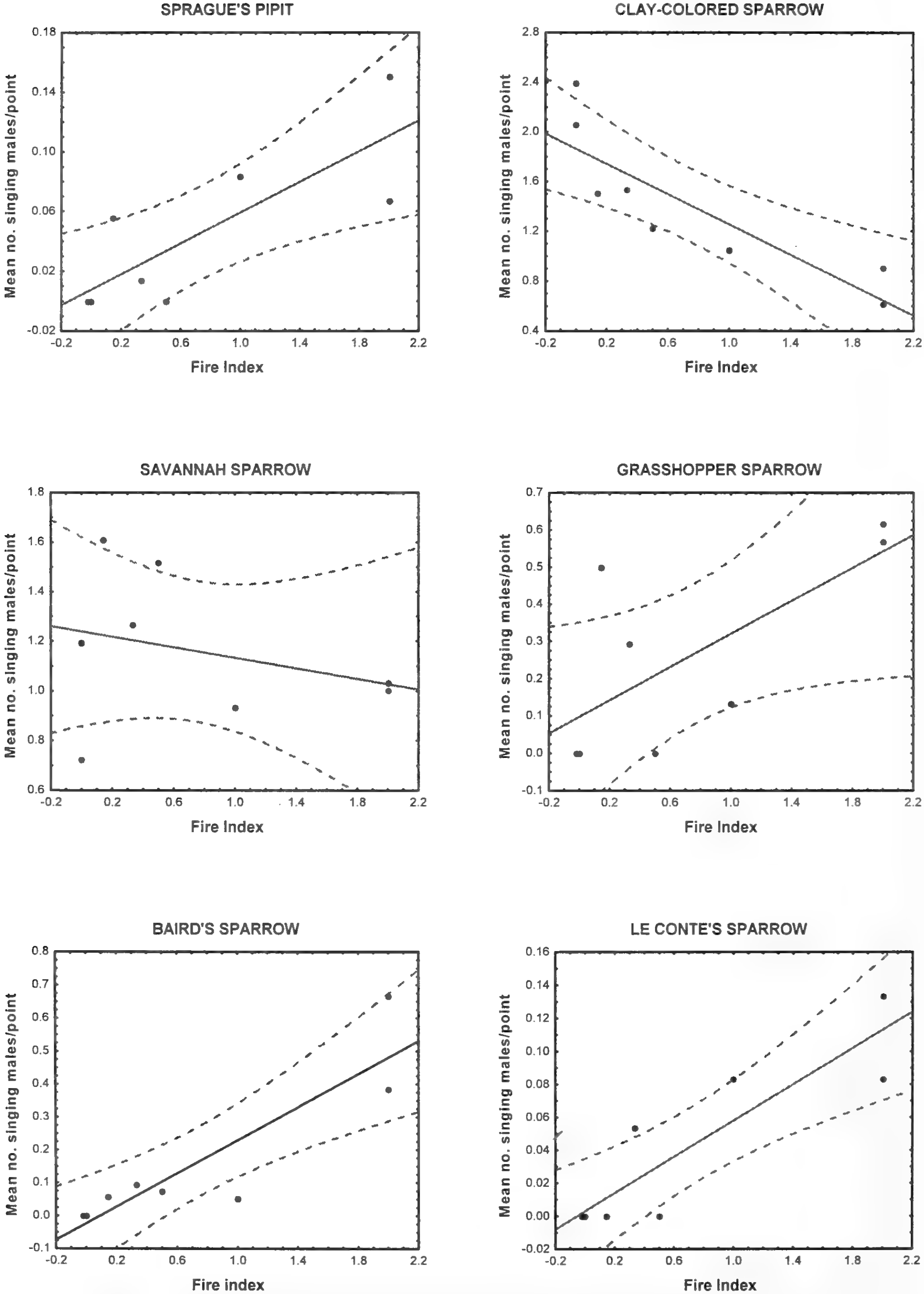

FIGURE 2. Observed relationships between bird species abundance and amount of fire, Lostwood National Wildlife Refuge, North Dakota, 1994. Abundance is mean number of singing males per point. See text for explanation of fire index. Dotted lines indicate 95% confidence intervals of the regression line.

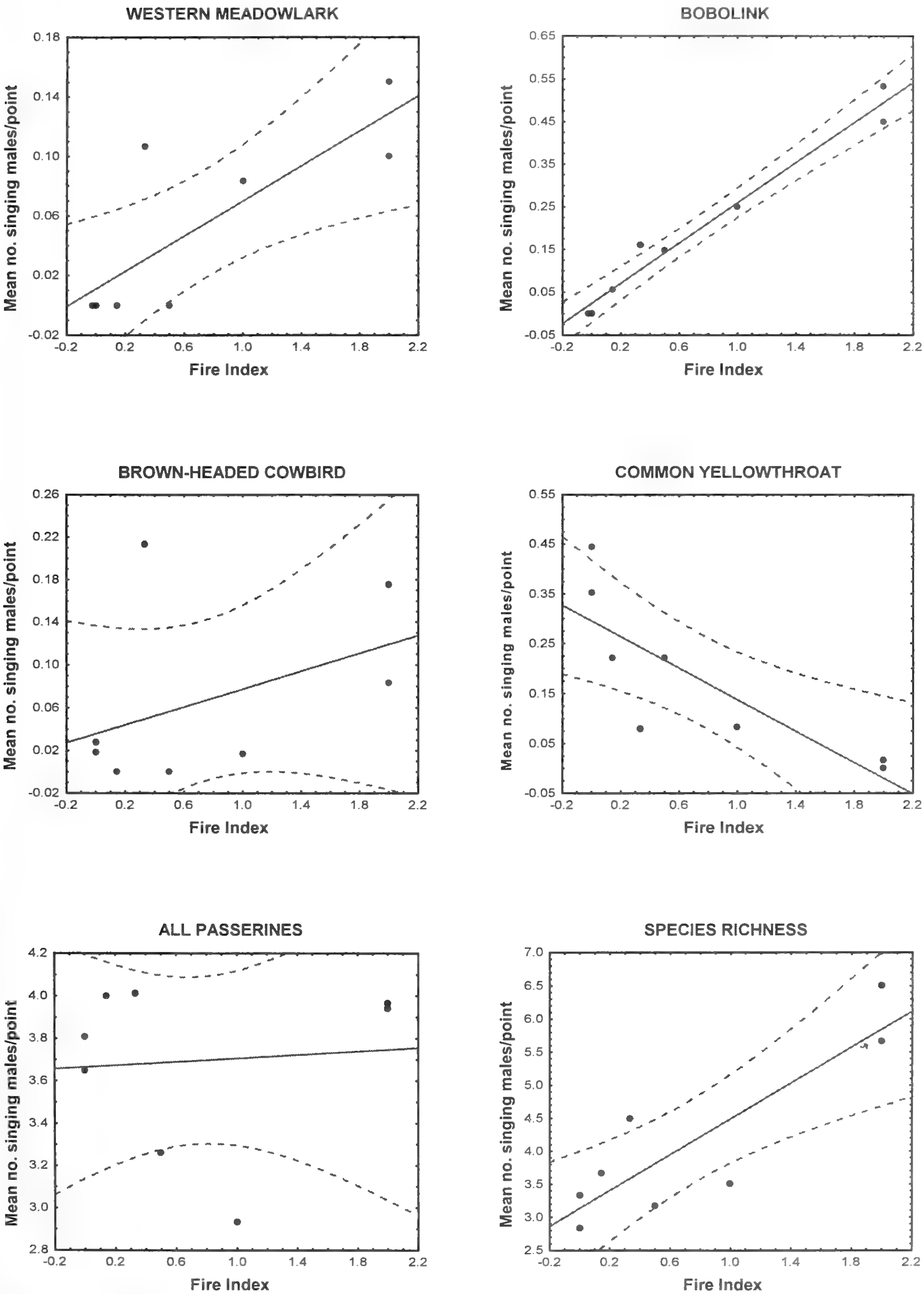

FIGURE 2. *(continued)*

postfire) (Madden 1996). In mixed-grass prairie, Chestnut-collared Longspurs use short, sparse cover that typically is associated with annual livestock grazing under heavy stocking rates (Kantrud 1981; Dale 1983; Renken 1983; Huber and Steuter 1984) or, historically, with frequent fire and Bison grazing (Knopf 1996). Longspurs were still abundant on Lostwood NWR in the 1930s when the refuge was created (Gabrielson 1943: 145). However, they disappeared by the 1970s after decades of fire suppression and either season-long grazing by cattle at light stocking rates, or no grazing at all (USFWS, Lostwood NWR, refuge files). After aggressive grassland management was initiated on Lostwood NWR in the late 1970s–1980s, longspurs began to re-colonize areas experiencing frequent fire. Although still relatively rare, Chestnut-collared Longspurs continue to be observed at Lostwood NWR, especially where grazing is beginning to be introduced following several prescribed burn treatments (USFWS, Lostwood NWR, unpublished report, 1998).

Role Of Fire in the Maintenance of Grasslands

Considering results from this study along with current thinking on fire frequency, we conclude that grassland vegetation and birds are strongly adapted to, and may depend on, frequent (every 5–10 years) fire in mesic parts of North America's northern mixed-grass prairie such as the Missouri Coteau of North Dakota.

Management at Lostwood NWR has successfully restored fire as a dynamic process in the mixed prairie, and abundances of breeding, endemic passerines have increased. Because the northern Great Plains supports several species of endemic passerines (e.g., Baird's Sparrow, Sprague's Pipit), conservation of habitats used by these species should be emphasized. Clay-colored Sparrows responded negatively to fire (although they were not completely absent from burned areas), however, indicating that a mosaic of all stages of fire succession is needed to provide suitable habitat for all birds present (Ryan 1990). Grassland species among other bird orders (Charadriformes, Galliformes, Anseriformes, Falconiformes) also respond positively to fire or decline in its absence on the northern Great Plains (Kirsch and Kruse 1973; Kirsch and Higgins 1976; Huber and Steuter 1984; Higgins et al. 1989; Murphy 1993) and would benefit from incorporation of fire into native prairie management.

Effects of fire on grassland communities both within and among sub-regions of the Great Plains are extremely variable (Wright and Bailey 1982; Bragg 1995), and factors such as the pre-burn vegetation community, soil conditions, season and frequency of burning, and grazing history all affect post-fire conditions. Appropriate sizes and configurations for burn units have not been established, and further study is warranted. On midwestern prairies, burning of 20–30% of an area each year is suggested as a general guideline for bird management on large (>80 ha) tracts (Herkert 1994). On extensive tracts of prairie such as Lostwood NWR, effects of large-scale burning on small, ecologically sensitive fauna such as butterflies (Lepidoptera) must also be considered (Oates 1995).

Managers of mesic, mixed-grass prairie generally should provide areas with short (2-4 year), moderate (5-7 year), and long (8-10 year, or more) fire return intervals to provide maximum grassland bird diversity. Combination of fire with other defoliation tools (grazing, mowing) will, of course, modify these intervals. Most grassland species we examined (Baird's Sparrow, Sprague's Pipit, Bobolink, Grasshopper Sparrow, Western Meadowlark, Le Conte's Sparrow) would benefit from short intervals, but Savannah Sparrow and Clay-colored Sparrow would likely be most abundant with moderate and long fire return intervals, respectively. Decisions on whether to emphasize any one fire frequency will depend on overall management goals, and thus include anticipated impacts on other native prairie biota (e.g., butterflies, amphibians). Because long-term rest may create habitat unfavorable for most species of grassland passerines in mesic, northern mixed prairie, periodic defoliations by disturbances such as fire should be considered essential to restore and maintain native biodiversity.

Acknowledgments

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Literature Cited

Arnold, T. W., and **K. F. Higgins.** 1986. Effects of shrub coverages on birds of North Dakota mixed-grass prairies. Canadian Field-Naturalist 100: 10–14.

Bluemle, J. P. 1980. Guide to the geology of northwestern North Dakota. Education Series 8, North Dakota Geologic Survey. 38 pages.

Bragg, T. B. 1995. Climate, soils and fire: The physical environment of North American grasslands. *In* The Changing Prairie. *Edited by* K. Keeler and A. Joerns. Oxford University Press, New York.

Buckland, S. T., K. P. Burnham, D. R. Anderson, and **J. L. Laake.** 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall, New York. 446 pages.

Chatterjee, S., and **B. Price.** 1991. Regression analysis by example. Second edition. John Wiley and Sons, New York. 278 pages.

Coues, E. 1878. Field notes on birds observed in Dakota and Montana along the forty-ninth parallel during the seasons of 1873 and 1874. United States Geologic and Geographic Survey Territorial Bulletin 4: 545–661.

Coupland, R. T. 1950. Ecology of mixed prairie in Canada. Ecological Monographs 20: 271–315.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43–64.

Daubenmire, R. 1968. Ecology of fire in grasslands. Advances in Ecological Research 5: 209–298.

Dobkin, D. S. 1992. Neotropical migrant landbirds in the northern Rockies and Great Plains. U.S.D.A. Forest Service-Northern Region. Publication Number R1-93-34. Missoula, Montana.

Droege, S., and **J. Sauer.** 1994. Are more North American species decreasing than increasing? Pages 297–306 *in* Bird Numbers 1992. Distribution, monitoring and ecological aspects. *Edited by* E. J. M. Hagemeijer and T. J. Verstrael. Proceedings of the 12th International Conference of IBCC and EOAC, Noordwijkerhout, The Netherlands, Statistics Netherlands, Voorburg/Heerlen and SOVON, Beek-Ubbergen.

Ehrenreich, J. H. 1959. Effect of burning and clipping on growth of native prairie in Iowa. Journal of Range Management 12: 133–137.

Forde, J. D., N. F. Sloan, and **D. A. Shown.** 1984. Grassland habitat management using prescribed fire in Wind Cave National Park, South Dakota. Prairie Naturalist 16: 97–110.

Gabrielson, I. N. 1943. Wildlife refuges. MacMillian, New York. 257 pages.

Gauch, H. G. 1982. Multivariate analysis in community ecology. Cambridge University Press, New York. 298 pages.

Goossen, J. P., S. Brechtel, K. D. DeSmet, D. Hjertaas, and **C. Wershler.** 1993. Canadian Baird's Sparrow Recovery Plan. Recovery of Nationally Endangered Wildlife Report Number 3. Canadian Wildlife Federation, Ottawa. 28 pages.

Herkert, J. R. 1994. Breeding bird communities of midwestern prairie fragments: the effects of prescribed burning and habitat-area. Natural Areas Journal 14: 128–135.

Higgins, K. F. 1986. Interpretation and compendium of historical fire accounts in the northern Great Plains. U.S. Fish and Wildlife Service Resource Publication 161. 39 pages.

Higgins, K. F., A. D. Kruse, and **J. L. Piehl.** 1989. Effects of fire in the northern Great Plains. South Dakota State University Extension Circular 760. 47 pages.

Huber, G. E., and **A. A. Steuter.** 1984. Vegetation profile and grassland bird response to spring burning. Prairie Naturalist 16: 55–61.

Hutto, R. L., S. M. Pletschet, and **P. Hendricks.** 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103: 593–602.

Johnson, D. H. 1996. Management of northern prairies and wetlands for the conservation of neotropical migratory birds. Pages 53–67 *in* Management of midwestern landscapes for the conservation of neotropical migratory birds. *Edited by* F. R. Thompson. U.S.D.A. Forest Service General Technical Report NC-187. St. Paul, Minnesota.

Johnson, D. H. 1997. Effects of fire on bird populations in mixed-grass prairie. Pages 181–206 *in* Ecology and conservation of Great Plains vertebrates. *Edited by* F. L. Knopf and F. B. Samson. Springer, New York.

Kantrud, H. A. 1981. Grazing intensity effects on the breeding avifauna of North Dakota native grasslands. Canadian Field-Naturalist 95: 404–417.

Kirsch, L. M., and **K. F. Higgins.** 1976. Upland Sandpiper nesting and management in North Dakota. Wildlife Society Bulletin 4: 16–22.

Kirsch, L. M., and **A. D. Kruse.** 1973. Prairie fires and wildlife. Proceedings of Tall Timbers Fire Ecology Conference 12: 289–303.

Kirsch, L. M., H. F. Duebbert, and **A. D. Kruse.** 1978. Grazing and haying effects on habitats of upland nesting birds. Transactions of the North American Wildlife and Natural Resources Conference 43: 486–497.

Knopf, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15: 247–257.

Knopf, F. L. 1996. Prairie legacies — birds. Pages 135–148 *in* Prairie conservation: preserving North America's most endangered ecosystem. *Edited by* F. Samson and F. Knopf. Island Press, Washington, D.C.

Knopf, F. L., and **F. B. Samson.** 1994. Scale perspectives on avian diversity in western riparian landscapes. Conservation Biology 8: 669–676.

Kucera, C. L. 1981. Grasslands and fire. Pages 90–111 *in* Fire regimes and ecosystem properties: proceedings of the conference. U.S.D.A. Forest Service General Technical Report WO-26. Washington, D.C. 594 pages.

Lowther, P. E. 1993. Brown-headed Cowbird (*Molothrus ater*). *In* The birds of North America Number 47. *Edited by* A. Poole and F. Gill. Philadelphia, Pennsylvania: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union. 24 pages.

Madden, E. M. 1996. Passerine communities and bird-habitat relationships on prescribe-burned mixed-grass prairie in North Dakota. M.S. thesis, Montana State University, Bozeman, Montana. 153 pages.

Murphy, R. K. 1993. History, nesting biology, and predation ecology of raptors in the Missouri Coteau of northwestern North Dakota. Ph.D. dissertation, Montana State University, Bozeman, Montana. 212 pages.

Oates, M. R. 1995. Butterfly conservation within the management of grassland habitats. Pages 98–112 *in* Ecology and conservation of butterflies. *Edited by* A. S. Pullin. Chapman Hall, New York.

Pylypec, B. 1991. Impacts of fire on bird populations in a fescue prairie. Canadian Field-Naturalist 105: 346–349.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and **D. F. DeSante.** 1993. Handbook of field methods for monitoring landbirds. U.S.D.A. Forest Service General Technical Report PSW-GTR-144. Albany, California. 41 pages.

Renken, R. B. 1983. Breeding bird communities and bird-habitat associations on North Dakota Waterfowl Production Areas. M.S. thesis, Iowa State University, Ames. 90 pages.

Robel, R. J., J. N. Briggs, A. D. Dayton, and **L. C. Hulbert.** 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23: 295–297.

Romo, J. T., and **P. L. Grilz.** 1990. Invasion of Canadian prairies by an exotic perennial. Blue Jay 48: 131–135.

Rotella, J. J., E. M. Madden, and **A. J. Hansen.** 1999. Sampling considerations for estimating abundance of passerines in grasslands. Studies in Avian Biology Number 19.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57: 773–782.

Ryan, M. R. 1990. A dynamic approach to the conservation of the prairie ecosystem in the Midwest. Pages 91–106 *in* Management of dynamic ecosystems. *Edited by* J. M. Sweeney. North Central Section, The Wildlife Society, West Lafayette, Indiana.

Samson, F. B., and **F. L. Knopf.** 1994. Prairie conservation in North America. Bioscience 44: 418–421.

Samson, F. B., and **F. L. Knopf.** *Editors.* 1996. Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D.C. 339 pages.

SAS Institute Inc. 1988. SAS/STAT User's Guide, Version 6, third edition. SAS Institute Inc., Cary, North Carolina. 1028 pages.

Stewart, R. E., and **H. A. Kantrud.** 1972. Population estimates of breeding birds in North Dakota. Auk 89: 766–788.

Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithological Monographs 8: 1–93.

Wilkinson, L. 1990. SYGRAPH: the system for graphics. SYSTAT Inc., Evanston, Illinois. 547 pages.

Wright, H. A., and **A. W. Bailey.** 1982. Fire ecology. John Wiley and Sons, New York. 501 pages.

Zimmerman, J. L. 1992. Density-independent factors affecting the avian diversity of the tallgrass prairie community. Wilson Bulletin 104: 85–94.

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Maritime Quillwort, *Isoetes maritima* (Isoetaceae), in the Yukon Territory

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Brunton, Daniel F., and Donald M. Britton. 1999. Maritime Quillwort, *Isoetes maritima* (Isoetaceae), in the Yukon Territory. Canadian Field-Naturalist 113(4): 641–645.

Maritime Quillwort, *Isoetes maritima* (Isoetaceae), is reported from a single location in southeastern Yukon Territory and is a new record for the flora of the Territory. The Yukon *I. maritima* population is compared to that of *I. echinospora*, also known from only one Yukon location. *Isoetes maritima* may have reached here as populations migrating eastward across the Yukon River watershed from the Beringian glacial refugium before coastal areas of northern British Columbia and adjacent southern Alaska had emerged from the Wisconsinan Cordilleran Ice Sheet. If so, isolated *I. maritima* populations could be expected at floristically diverse aquatic sites elsewhere along the Yukon River watershed.

Key Words: Maritime Quillwort, *Isoetes maritima*, distribution, Beringia, refugium, Yukon Territory, Canada.

Maritime Quillwort, *Isoetes maritima* Underw., is a locally common pteridophyte of shallowly flooded and emergent fresh-water lake and river shores along the western coast of North America, ranging from Washington State to the Aleutian Islands of western Alaska (Taylor et al. 1993). It is a small (rarely 15 cm tall) herbaceous plant with a bundle of simple, fleshy, quill-like leaves arising from a central corm. The plant is typically anchored in nutrient-poor, slightly acidic, coarse sand or silty-sand substrate. Distinctively-ornamented megaspores and microspores are contained within oval sporangia situated at the base of the inner side of fertile leaves.

Isoetes maritima rarely occurs more than 50 km inland, being common further east only in the "interior wet belt" Columbia Forest Region of south-central British Columbia which shares climatic and vegetational affinities with the Pacific coast (Rowe 1972; Lavender et al. 1990; Britton and Brunton 1995) and in a similar interior area of east central Alaska (Britton, Brunton, and Talbot 1999). An isolated disjunct population occurs at one site in western Alberta which has floristic and faunal affinities with interior British Columbia (Britton and Brunton 1993). The discovery of a far-inland population in southeastern Yukon Territory, therefore, was unexpected and raises interesting phytogeographic questions.

Existing status

The Yukon Territory record for *Isoetes maritima* is based on a collection from Sheldon Lake in the Ross River Valley of the Selwyn Mountains [62° 42′ N, 131° 03′ W]. Label data for that collection are as follows: "in shallow water near S end of Sheldon Lake [near the trading post], elev. 3000′, Canol Road Mile 222, *A.E. Porsild and A.J. Breitung 11,502*, 17 August 1944" (CAN, S!, GH!). It was originally identified as *Isoetes echinospora* Dur. (*I. braunii* Dur.). Porsild (1951) believed this to be the only Yukon Territory population of the latter which is a transcontinental, but primarily more southern species (Cody 1996). This interpretation was supported in later floristic assessments (e.g., Douglas et al. 1981; Cody and Britton 1989).

Identification and spore ornamentation

The tetraploid *Isoetes maritima* ($2n = 44$) is very similar in appearance to diploid *I. echinospora* ($2n = 22$) and has been treated as a variety of the latter by some authors (*I. echinospora* var. *maritima* (Underw.) A. Love). The discovery of their sterile triploid hybrid *I. Xpseudotruncata* Britton and Brunton ($2n = 33$), however, confirmed that they are distinct species (Britton and Brunton 1996).

Spore ornamentation is critical to the identification of most North American *Isoetes* (Kott and Britton 1983; Taylor et al. 1993). In the absence of living material from which to determine if the Sheldon Lake population is diploid or tetraploid, we identified *Porsild and Breitung 11,502* from a diagnostic combination of spore ornamentation characteristics.

Plants of the *Porsild and Breitung 11,502* collection were found to have densely echinate megaspores covered with the broad-based spines which taper quickly and end in sharp, irregular tips. The spines also become progressively smaller towards the equatorial ridge (Figure 1). These are typical of *I. maritima* (Taylor et al. 1993; Britton and Brunton 1995; Britton, Brunton and Talbot 1999). *Isoetes echinospora* megaspore spines on the other hand (Figure 2) are longer, more evenly tapered to a regular, sharp point and are often thinner and less densely distributed. They are more or less uniform in size

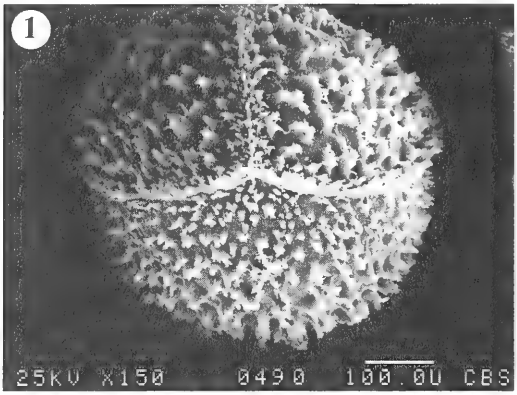

FIGURE 1. Lateral view of *Isoetes maritima* megaspore (*Porsild & Breitung 11,502,* Sheldon Lake, Yukon Territory [GH]; Scale bar = 100 µm).

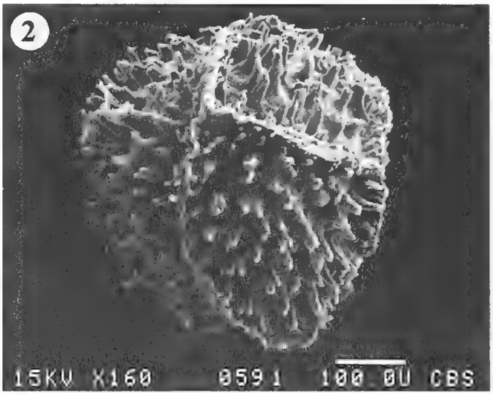

FIGURE 2. Lateral view of *Isoetes echinospora* megaspore (*Britton 9,523*, Parry Sound District, Ontario [OAC]; Scale bar = 100 µm).

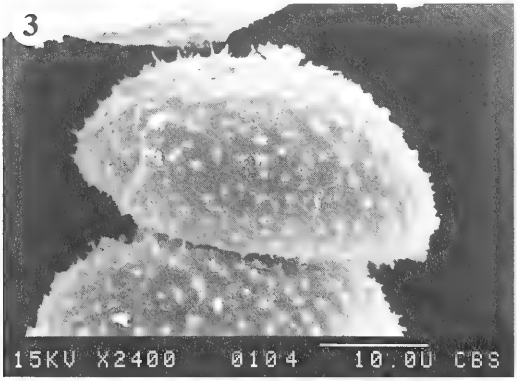

FIGURE 3. Microspores of *Isoetes maritima* (*Porsild & Breitung 11,502,* Sheldon Lake, Yukon Territory [S]; Scale bar = 10 µm).

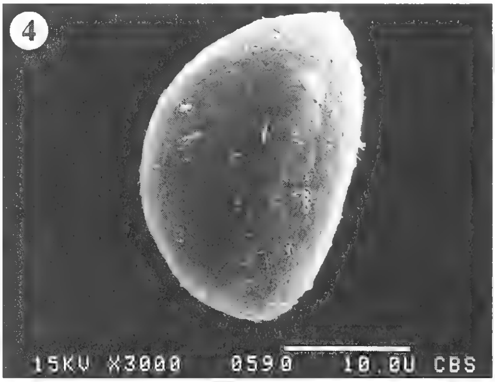

FIGURE 4. Microspore of *Isoetes echinospora* (*Britton 9,523*, Parry Sound District, Ontario [OAC]; Scale bar = 10 m).

throughout (Taylor et al. 1993; Britton and Brunton 1996; Britton, Brunton, and Talbot 1999). The slightly flattened proximal hemisphere and swollen distal hemisphere of many *I. maritima* megaspores also gives them a somewhat "acorn-like" profile, in contrast to the usually round shape of *I. echinospora* megaspores.

The microspores of *Porsild and Breitung 11,502* plants are relatively large (34.0 µm, N = 20). Even though they appear to be slightly immature, these microspores exhibit the spine-tipped pauperculate ornamentation indicative of *I. maritima* (Figure 3). *Isoetes echinospora* microspores on the other hand (Figure 4), are smooth-surfaced and significantly smaller (26.0 µm - Brunton and Britton 1996; Britton, Brunton, and Talbot 1999).

We also examined the single additional collection of *Isoetes* known from the Yukon; it is from the southeastern portion of the Territory as well (Rosie 1991; Cody 1996). The label data for that collection states: "on mud and sand bottom, shallow water along shore of lake, Hour Lake, near Frances Lake, 61° 11′ N, 129° 08′ W, *R. Rosie 897*, 29 September 1979" (DAO!, VIC!). These plants exhibit the densely echinate megaspores covered with long, thin-pointed, narrow spines indicative of *I. echinospora*. The latter, then, constitutes the only known Yukon Territory population of *I. echinospora* (Figure 5).

Habitat and Site

Sheldon Lake is atypical of the spring-fed, clearwater lakes of this area of the Yukon Territory, occupying a shallow depression in a thick deposit of boulder clay over sedimentary bedrock in the wide, glaciated Ross River Valley. It is also characterized by milky-coloured water and, as with nearby Field and Lewis lakes, receives a heavy load of sediment from the Ross River. Extensive marshes and mud flats are found around the lake (Porsild 1951). This area in the upper Yukon River watershed is at the

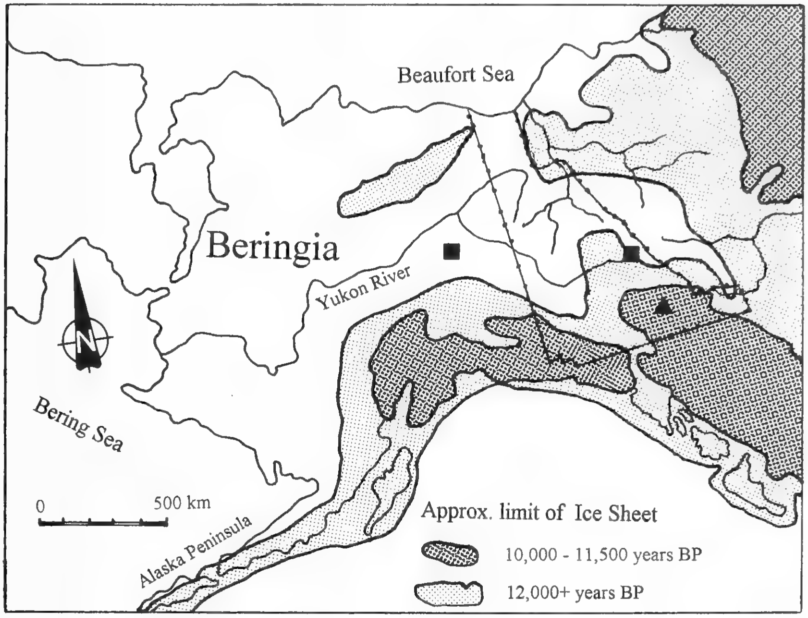

FIGURE 5. Yukon Territory (dotted line) distribution of *Isoetes* in relation to Beringian landbase ca. 10 000 - 11 500 years BP. Solid square = *Isoetes maritima*, solid triangle = *Isoetes echinospora*. Location of inland *I. maritima* in Alaska also noted. (Quaternary information from Roberts et al. 1987; Prest et al. 1987; Schweger 1989).

point where well-drained White Spruce (*Picea glauca* (Moench) Voss)/ White Birch (*Betula papyrifera* Marsh.)/ Black Spruce (*Picea mariana* (Mill.) BSP.) dominated forest gives way to more boggy Black Spruce dominated forest at the western approaches to the Macmillan Pass entrance into the Mackenzie Mountains (Porsild 1951).

The Sheldon Lake - Sheldon Mountain area of the Ross River Valley has been identified as a centre of diversity for rare Yukon Territory flora (Douglas et al. 1981). This floristic richness is indicated by the presence of 19 territorially rare species of which *Isoetes maritima*, *Potamogeton subsibiricum* Hagstr. and *Potamogeton obtusifolius* Mert. & Koch. are known elsewhere in the Yukon Territory from one other location at most (Douglas et al. 1981; Cody et al. 1998).

Origin and dispersal

At their closest, contemporary populations of *Isoetes maritima* in coastal southern Alaska are separated by ca. 500 km and across several mountain ranges from the Sheldon Lake population and are not connected to it by river systems. Disjunct interior British Columbia *I. maritima*, on the other hand, is less than 200 km from the species' primary coastal range and is connected directly to those populations by major river systems (Britton and Brunton 1995). The apparently isolated populations in the Fairbanks areas of eastern interior Alaska are over 900 km west of the Sheldon Lake population but occur within the same drainage system, the Yukon River.

Much of the Yukon River watershed was unglaciated during the Wisconsinan glaciation when the Cordilleran and Laurentide ice sheets covered much of northern North America (Dyke and Prest 1987). The unglaciated corridor across the Yukon River watershed constituted the eastern portion of Beringia, serving both as a glacial era refugium and a post-glacial floristic and faunal migration corridor (Hulten 1968; Schweger 1989). The Alaska - British Columbia coastal band along which *Isoetes maritima* is common today, however, as well as the intervening interior mountains, continued to be covered in glacial ice sheets during this time (Hughes et al. 1989) (Figure 5).

Towards the end of the Wisconsinan glaciation period ca. 10 000 to 12 000 year BP, much of the western Yukon was characterized by a tundra-Boreal vegetation dominated by spruce and poplar forest (McAndrews et al. 1987). Although the chronology of these events is unclear, there is strong paleobotanical evidence of a period of warmer, moister climate at this time (Schweger 1989). As the ice sheets continued to decay, *Isoetes maritima* and other species of more temperate, coastal environments could have migrated eastward along the Yukon River into the ice-free Yukon interior. A prolonged warm period would presumably have expanded the availability of suitable aquatic habitat.

The possibility of a refugial/post-glacial migration origin for inland *Isoetes maritima* appears to be supported by the presence of the isolated *I. maritima* populations along lower tributaries of the Yukon River near Fairbanks, Alaska. *Isoetes maritima* may have been eliminated from all but isolated, particularly suitable sites like that apparently existing at Sheldon Lake, by climatic cooling to present day conditions. If that is the case, additional populations of this aquatic pteridophyte could reasonably be expected in the Yukon River watershed at diverse aquatic sites demonstrating floristic affinities with interior Alaska.

If *Isoetes maritima* distribution in the Yukon Territory and other interior Alaska-Yukon sites does not reflect that of a Beringian relict, long-distance dispersal of quillwort spores or plants would have to be invoked to explain its occurrence at locations across several hundred kilometers of largely unsuitable habitat. Transportation by birds, especially waterfowl, has been suggested as a possible vehicle for the distribution of numerous aquatic quillworts; Canada Geese (*Branta canadensis*) and Mallards (*Anas platyrhynchos*) have been observed grazing on *I. echinospora* and *I. macrospora* Dur. in eastern North America (W. C. Taylor, personal communication; personal observation), and Common Loon (*Gavia immer*) have been seen uprooting and possibly eating *I. maritima* and *I. occidentalis* Hend. plants in interior British Columbia (T. Goward, personal communication). It does not appear likely, however, that these isolated, interior quillwort sites are visited by large numbers of primarily coastal waterfowl. Further, plants bearing mature sporangia would only be available to browsing waterfowl in late summer during the *southward* migration period.

We have uncovered no evidence of *Isoetes maritima* populations from elsewhere in northern Canada. In addition to all Yukon Territory material, we also examined vouchers from the Northwest Territories *Isoetes* stations noted in Cody and Britton (1989) and/or those maintained in the CAN, DAO, GH, OAC, S, SASK, TRT, and V herbaria (mostly from the Great Bear Lake - Lake Athabaska region). All collections examined have been identified either as *I. echinospora* or the primarily eastern and more southern decaploid *I. macrospora* ($2n = 110$).

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Literature Cited

Britton, D. M., and **D. F. Brunton.** 1993. *Isoetes Xtruncata*: a newly considered pentaploid hybrid from western Canada. Canadian Journal of Botany 71: 1016–1025.

Britton, D. M., and **D. F. Brunton.** 1995. *Isoetes Xmarensis*, a new interspecific hybrid from western Canada. Canadian Journal of Botany 73: 1345–1353.

Britton, D. M., and **D. F. Brunton.** 1996. *Isoetes Xpseudotruncata*, a new triploid hybrid from western Canada and Alaska. Canadian Journal of Botany 74: 51–59.

Britton, D. M., D. F. Brunton, and **S. S. Talbot**. 1999. *Isoetes* in Alaska and the Aleutians. American Fern Journal 79: 133–141.

Cody, W. J. 1996. The flora of the Yukon Territory. National Research Council Press, Ottawa. 643 pages.

Cody, W. J., and **D. M. Britton.** 1989. Ferns and fern allies of Canada. Publication 1829/E, Research Branch, Agriculture Canada, Ottawa. 430 pages.

Cody, W. J., C. E. Kennedy, and **B. Bennett.** 1998. New records of vascular plants in the Yukon Territory. Canadian Field-Naturalist 112: 289–328.

Douglas, D. G., G. W. Argus, H. L. Dickson, and **D. F. Brunton.** 1981. The rare vascular plants of the Yukon. Syllogeus 28. 96 pages.

Dyke, A. S., and **V. K. Prest.** 1987. Paleogeography of northern North America, 18,000 - 5,000 years ago. Map 1703A, Sheet 1: 18 000 - 12 000 years BP. Geological Survey of Canada, Ottawa.

Hughes, O. L., N. W. Rutter, and **J. J. Clague.** 1989. Yukon Territory (Quaternary stratigraphy and history, Cordilleran Ice Sheet); Pages 58–62, Chapter 1 *in* Quaternary Geology of Canada and Greenland, *Edited by* R. J. Fulton. Geological Survey of Canada, Ottawa. 839 pages.

Hulten, E. 1968. Flora of Alaska and neighbouring territories, a manual of the vascular plants. Stanford University Press, Stanford. 1008 pages.

Kott, L. S., and **D. M. Britton.** 1983. Spore morphology and taxonomy of *Isoetes* in northeastern North America. Canadian Journal of Botany 61: 3140–3164.

Lavender, D. P, R. Parish, C. M. Johnson, G. Montgomery, A. Vyse, R. A. Willis, and **D. Winston.** *Editors*. 1990. Regenerating British Columbia's Forests. University of British Columbia Press, Vancouver. 372 pages.

McAndrews, J. H., K. B. Liu, G. C. Manville, V. K. Prest, and **J.-S. Vincent.** 1987. Environmental Changes after 9000 BC *in* Historical Atlas of Canada, Volume 1: From the beginning to 1800. *Edited by* R. C. Harris. University of Toronto Press, Toronto.

Porsild, A. E. 1951. Botany of southeastern Yukon adjacent to the Canol Road. National Museum of Canada Bulletin 121, Canada Department of Resources and Development, Ottawa. 400 pages.

Prest, V. K., J.-S. Vincent, and **J. H. McAndrews.** 1987. The last ice sheets, 18,000-10,000 BC *in* Historical Atlas of Canada, Volume 1: From the beginning to 1800. *Edited by* R. C. Harris. University of Toronto Press, Toronto.

Roberts, A., J. H. McAndrews, V. K. Prest, and **J.-S. Vincent.** 1987. The Fluted Point People, 9500-8,200 BC *in* Historical Atlas of Canada, Volume 1: From the beginning to 1800. *Edited by* R. C. Harris. University of Toronto Press, Toronto.

Rosie, R. 1991. Range extensions and rare vascular plants from southeastern Yukon Territory. Canadian Field-Naturalist 105: 315–324.

Rowe, J. S. 1972. Forest Regions of Canada. Canadian Forest Service, Ottawa.

Schweger, C. E. 1989. Paleoecology of the western Canadian ice-free corridor *in* Chapter 1, Quaternary Geology of Canada and Greenland. *Edited by* R. J. Fulton. Geological Survey of Canada, Ottawa. 839 pages.

Taylor, W. C., N. T. Luebke, D. M. Britton, R. J. Hickey, and **D. F. Brunton.** 1993. Isoetaceae. Pages 64-75 *in* Flora of North America North of Mexico. Volume 2. *Edited by* FNA Editorial Committee. Oxford University Press, New York and Oxford. 475 pages.

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Uncommon Breeding Birds in North Dakota: Population Estimates and Frequencies of Occurrence

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Breeding bird populations were surveyed on 128 randomly selected quarter-sections throughout North Dakota in 1967, 1992, and 1993. Population estimates and frequencies of occurrence are reported for 92 uncommon breeding bird species with statewide frequencies of less than 10%.

Key Words: frequency of occurrence, population estimate, uncommon breeding birds, North Dakota.

Population estimates for birds over large geographic areas in North America are decidedly rare and usually limited to game species (e.g., waterfowl: U.S. Fish and Wildlife Service 1997), certain taxonomic groups (e.g., seabirds: Ainley et al. 1994), or species of conservation concern (e.g., Piping Plover [*Charadrius melodus*]: Haig and Plissner 1993; Baird's Sparrow [*Ammodramus bairdii*]: Skeel et al. 1995*). Notable exceptions are population estimates derived from surveys of breeding birds in Illinois (Forbes 1913; Forbes and Gross 1922, 1923; Graber and Graber 1963), North Dakota (Stewart and Kantrud 1972; Igl and Johnson 1997), and the Platte River Valley in Nebraska (Faanes 1991*; Faanes and Lingle 1995*). The North American Breeding Bird Survey, a primary source of data on populations for many species of North American breeding birds, by design, provides indices to population change rather than estimates of continental or regional breeding bird populations (Robbins et al. 1986).

In 1967, Stewart and Kantrud (1972) conducted an extensive survey of breeding bird populations throughout North Dakota to obtain baseline estimates of statewide breeding bird abundance and frequency of occurrence. They recorded 131 species of breeding birds on 130 randomly selected quarter-sections. In 1992 and 1993, Igl and Johnson (1997) repeated the Stewart-Kantrud survey using the same sample units and methods to examine changes in breeding bird populations in North Dakota between 1967 and 1992–1993. Igl and Johnson (1997) observed 144 breeding bird species in 1992 and 153 in 1993.

In both studies (Stewart and Kantrud 1972; Igl and Johnson 1997), statewide population estimates were published for only the more common breeding bird species in North Dakota. Population estimates for the uncommon species (defined here as those with frequencies of occurrence of less than 10%) were never published, although this information has occasionally been requested or sought (Robbins et al. 1986: 128; Page and Gill 1994; Houston et al. 1998). In this paper, we present frequencies of occurrence and statewide population estimates for the uncommon species in 1967, 1992, and 1993.

Study Area and Methods

The study area and methods were described in detail by Stewart and Kantrud (1972) and Igl and Johnson (1997) and are only summarized here. In 1967, Stewart and Kantrud (1972) surveyed breeding birds on 130 randomly selected quarter-sections (about 64.7 ha each) throughout North Dakota. To facilitate a direct comparison, the same sample units and methods used by Stewart and Kantrud (1972) in 1967 were used by Igl and Johnson (1997) in 1992 and 1993. Igl and Johnson (1997), however, visited only 128 of the 130 quarter-sections originally surveyed by Stewart and Kantrud (1972) in 1967; landowners denied access to the other two quarter-sections. Comparisons among years are based on the 128 quarter-sections that were surveyed in all three years.

Breeding bird surveys were conducted between late April and mid-July each year by two observers on foot (Stewart and Kantrud 1972). Each observer surveyed breeding birds on a rectangular half of a quarter-section by following a standardized survey route. The rectangular halves were usually surveyed simultaneously and an interval of about 400 m was maintained between observers. Species were identified by sight or sound. We avoided censusing during precipitation and strong winds (> 24 km/h). We conducted surveys of birds in open habitats between 0.5 h after sunrise and 0.5 h before sunset. Quarter-sections containing extensive woodland habitats were usually surveyed on relatively calm (< 8 km/h), sunny days between 0.5 h after sunrise and 10:00 CDT. Counts of breeding birds were based primarily on the numbers of indicated breeding pairs during peak breeding periods.

TABLE 1. Statewide frequencies of occurrence (with 95% confidence interval) and statewide breeding population estimates (1000s of pairs, with 95% confidence intervals) of uncommon species of birds (i.e., species with frequencies less than 10%) in North Dakota in 1967, 1992, and 1993.

Species	Frequency of occurrence (CI)			Population estimate (CI)		
	1967	1992	1993	1967	1992	1993
Pied-billed Grebe (*Podilymbus podiceps*)	5.5 (2.1-10.0)	2.3 (0.4-5.5)	3.1 (0.8-6.5)	24 (4-44)	9 (0-17)	15 (0- 29)
Horned Grebe (*Podiceps auritus*)	1.6 (0.1-4.6)	0.8 (0.0-4.1)	0	4 (0-9)	2 (0-6)	0
Red-necked Grebe (*Podiceps grisegena*)	0	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-6)	2 (0-5)
Eared Grebe (*Podiceps nigricollis*)	2.3 (0.4-5.5)	0.8 (0.0-4.1)	2.3 (0.4-5.5)	90 (0-188)	108 (0-294)	49 (0-119)
Western Grebe (*Aechmophorus occidentalis*)	0	1.6 (0.1-4.6)	0.8 (0.0-4.1)	0	4 (0-10)	2 (0-6)
American White Pelican (*Pelecanus erythrorhynchos*)	0	0	0.8 (0.0-4.1)	0	0	4 (0-12)
Double-crested Cormorant (*Phalacrocorax auritus*)	0	0.8 (0.0-4.1)	2.3 (0.4-5.5)	0	2 (0-6)	22 (0-50)
American Bittern (*Botaurus lentiginosus*)	6.3 (2.7-10.8)	0.8 (0.0-4.1)	4.7 (1.6-9.0)	19 (6-32)	4 (0-12)	17 (3-31)
Great Blue Heron (*Ardea herodias*)	1.6 (0.1-4.6)	0.8 (0.0-4.1)	2.3 (0.4-5.5)	4 (0-9)	2 (0-6)	7 (0-13)
Black-crowned Night-Heron (*Nycticorax nycticorax*)	6.3 (2.7-10.8)	2.3 (0.4-5.5)	3.1 (0.8-6.5)	37 (0-70)	11 (0-22)	11 (0-21)
Turkey Vulture (*Cathartes aura*)	1.6 (0.1-4.6)	0	0.8 (0.0-4.1)	4 (0-9)	0	2 (0-6)
Canada Goose (*Branta canadensis*)	0	1.6 (0.1-4.6)	4.7 (1.6-9.0)	0	24 (0-63)	62 (0-133)
Wood Duck (*Aix sponsa*)	0.8 (0.0-4.1)	1.6 (0.1-4.6)	3.9 (1.1-8.1)	2 (0-6)	4 (0-10)	25 (0-47)
Cinnamon Teal (*Anas cyanoptera*)	0	0.8 (0.0-4.1)	0	0	2 (0-6)	0
Canvasback (*Aythya valisineria*)	1.6 (0.1-4.6)	3.1 (0.8-6.5)	1.6 (0.1-4.6)	22 (0-57)	9 (1-17)	10 (0-24)
Redhead (*Aythya americana*)	5.5 (2.1-10.0)	4.7 (1.6-9.0)	7.0 (3.2-11.9)	59 (0-115)	42 (0-85)	91 (0-174)
Ring-necked Duck (*Aythya collaris*)	0.8 (0.0-4.1)	0	0.8 (0.0-4.1)	4 (0-11)	0	2 (0-6)
Lesser Scaup (*Aythya affinis*)	2.3 (0.4-5.5)	0.8 (0.0-4.1)	0.8 (0.0-4.1)	6 (0-13)	9 (0-24)	9 (0-24)
Bufflehead (*Bucephala albeola*)	0	0	0.8 (0.0-4.1)	0	0	2 (0-6)
Hooded Merganser (*Lophodytes cucullatus*)	0	0	1.6 (0.1-4.6)	0	0	4 (0-9)
Ruddy Duck (*Oxyura jamaicensis*)	3.9 (1.1-8.1)	0.8 (0.0-4.1)	4.7 (1.6-9.0)	80 (0-160)	126 (0-342)	50 (0-9)
Sharp-shinned Hawk (*Accipiter striatus*)	0	0.8 (0.0- 4.1)	0	0	2 (0-5)	0
Cooper's Hawk (*Accipiter cooperii*)	2.3 (0.4-5.5)	1.6 (0.1- 4.6)	6.3 (2.7-10.8)	6 (0-13)	4 (0-9)	17 (6-29)
Broad-winged Hawk (*Buteo platypterus*)	0	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-6)	2 (0-5)
Ferruginous Hawk (*Buteo regalis*)	3.1 (0.8-6.5)	3.1 (0.8-6.5)	6.3 (2.7-10.8)	9 (1-17)	9 (1-17)	18 (6-29)
Golden Eagle (*Aquila chrysaetos*)	0	1.6 (0.1-4.6)	2.3 (0.4-5.5)	0	4 (0-8)	7 (0-13)
American Kestrel (*Falco sparverius*)	0	2.3 (0.4-5.5)	2.3 (0.4-5.5)	11 (2-20)	21 (5-37)	24 (7-41)
Prairie Falcon (*Falco mexicanus*)	0	2.3 (0.4-5.5)	2.3 (0.4-5.5)	0	6 (0-12)	6 (0-12)
Wild Turkey (*Meleagris gallopavo*)	0	0	2.3 (0.4-5.5)	0	0	7 (0-13)
Yellow Rail (*Coturnicops noveboracensis*)	0	0.8 (0.0-4.1)	0	0	2 (0-6)	0
Virginia Rail (*Rallus limicola*)	2.3 (0.4-5.5)	2.3 (0.4-5.5)	1.6 (0.1-4.6)	7 (0-13)	11 (0-23)	4 (0-9)
Piping Plover (*Charadrius melodus*)	1.6 (0.1-4.6)	0.8 (0.0-4.1)	0.8 (0.0-4.1)	11 (0-27)	4 (0-12)	2 (0-6)
American Avocet (*Recurvirostra americana*)	3.9 (1.1-8.1)	2.3 (0.4-5.5)	4.7 (1.6-9.0)	31 (3-59)	13 (0-26)	29 (0-57)
Spotted Sandpiper (*Actitis macularia*)	7.8 (3.9-12.6)	6.3 (2.7-10.8)	4.7 (1.6-9.0)	26 (9-42)	26 (5-47)	19 (3-36)
Common Snipe (*Gallinago gallinago*)	0	1.6 (0.1-4.6)	5.5 (2.1-10.0)	0	4 (0-10)	15 (4-26)
Franklin's Gull (*Larus pipixcan*)	5.5 (2.1-10.0)	2.3 (0.4-5.5)	2.3 (0.4-5.5)	48 (8-88)	171 (0-360)	125 (0-325)
Ring-billed Gull (*Larus delawarensis*)	0.8 (0.0-4.1)	3.1 (0.8-6.5)	5.5 (2.1-10.0)	2 (0-6)	106 (0-211)	24 (2-46)

Continued

TABLE 1. *Continued*

Species	Frequency of occurrence (CI)			Population estimate (CI)		
	1967	1992	1993	1967	1992	1993
California Gull (*Larus californicus*)	0	0	1.6 (0.1-4.6)	0	0	4 (0-10)
Common Tern (*Sterna hirundo*)	0.8 (0.0-4.1)	1.6 (0.1-4.6)	1.6 (0.1-4.6)	13 (0-36)	13 (0-33)	7 (0-15)
Forster's Tern (*Sterna forsteri*)	1.6 (0.1-4.6)	1.6 (0.1-4.6)	1.6 (0.1-4.6)	6 (0-15)	13 (0-33)	9 (0-21)
Rock Dove (*Columba livia*)	0	4.7 (1.6-9.0)	5.5 (2.1-10.0)	0	50 (0-113)	26 (5-48)
Great Horned Owl (*Bubo virginianus*)	1.6 (0.1-4.6)	3.1 (0.8-6.5)	7.0 (3.2-11.9)	4 (0-9)	9 (1-16)	19 (7-31)
Burrowing Owl (*Athene cunicularia*)	1.6 (0.1-4.6)	2.3 (0.4-5.5)	1.6 (0.1-4.6)	7 (0-15)	7 (0-13)	5 (0-10)
Long-eared Owl (*Asio otus*)	0	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-5)	2 (0-6)
Short-eared Owl (*Asio flammeus*)	0	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-6)	2 (0-6)
Chimney Swift (*Chaetura pelagica*)	0.8 (0.0-4.1)	0	2.3 (0.4-5.5)	2 (0-6)	0	6 (0-13)
Ruby-throated Hummingbird (*Archilochus colubris*)	0	3.1 (0.8-6.5)	0	0	9 (1-16)	0
Belted Kingfisher (*Ceryle alcyon*)	0	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-6)	2 (0-6)
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	1.6 (0.1-4.6)	4.7 (1.6-9.0)	3.9 (1.1-8.1)	4 (0-9)	20 (4-35)	15 (0-28)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	0	0	1.6 (0.1-4.6)	0	0	4 (0-9)
Hairy Woodpecker (*Picoides villosus*)	1.6 (0.1-4.6)	7.0 (3.2-11.9)	7.8 (3.9-12.6)	4 (0-9)	26 (9-43)	23 (9-38)
Red-shafted Flicker (*Colaptes auratus cafer*)	5.5 (2.1-10.0)	3.9 (1.1-8.1)	3.1 (0.8-6.5)	25 (5-44)	10 (2-19)	9 (1-17)
Pileated Woodpecker (*Dryocopus pileatus*)	0	0	0.8 (0.0-4.1)	0	0	2 (0-6)
Eastern Wood-Pewee (*Contopus virens*)	1.6 (0.1-4.6)	3.1 (0.8-6.5)	2.3 (0.4-5.5)	4 (0-9)	21 (0-40)	14 (0-29)
Alder Flycatcher (*Empidonax alnorum*)	0	0	0.8 (0.0-4.1)	0	0	2 (0-6)
Eastern Phoebe (*Sayornis phoebe*)	0.8 (0.0-4.1)	1.6 (0.1-4.6)	2.3 (0.4-5.5)	4 (0-11)	4 (0-9)	6 (0-11)
Great Crested Flycatcher (*Myiarchus crinitus*)	0.8 (0.0-4.1)	2.3 (0.4-5.5)	3.1 (0.8-6.5)	6 (0-16)	17 (0-34)	26 (3-50)
Yellow-throated Vireo (*Vireo flavifrons*)	0	0	0.8 (0.0-4.1)	0	0	4 (0-11)
Red-eyed Vireo (*Vireo olivaceus*)	3.9 (1.1-8.1)	3.1 (0.8-6.5)	6.3 (2.7-10.8)	27 (0-52)	42 (0-81)	86 (16-157)
Black-billed Magpie (*Pica pica*)	4.7 (1.6-9.0)	6.3 (2.7-10.8)	7.0 (3.2-11.9)	40 (6-75)	32 (7-57)	33 (10-56)
Purple Martin (*Progne subis*)	1.6 (0.1-4.6)	0.8 (0.0-4.1)	0	4 (0-9)	2 (0-6)	0
Tree Swallow (*Tachycineta bicolor*)	2.3 (0.4-5.5)	3.9 (1.1-8.1)	6.3 (2.7-10.8)	6 (0-13)	11 (2-19)	26 (8-44)
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	2.3 (0.4-5.5)	0.8 (0.0-4.1)	1.6 (0.1-4.6)	15 (0-32)	2 (0-6)	7 (0-16)
White-breasted Nuthatch (*Sitta carolinensis*)	0.8 (0.0-4.1)	3.9 (1.1-8.1)	5.5 (2.1-10.0)	6 (0-16)	15 (2-28)	19 (4-34)
Rock Wren (*Salpinctes obsoletus*)	3.1 (0.8-6.5)	4.7 (1.6-9.0)	4.7 (1.6-9.0)	20 (2-37)	46 (12-80)	58 (14-101)
Sedge Wren (*Cistothorus platensis*)	3.1 (0.8-6.5)	4.7 (1.6-9.0)	6.3 (2.7-10.8)	22 (0-49)	43 (5-81)	80 (0-187)
Eastern Bluebird (*Sialia sialis*)	0	3.1 (0.8-6.5)	3.1 (0.8-6.5)	0	8 (1-16)	11 (0-20)
Mountain Bluebird (*Sialia currucoides*)	3.1 (0.8-6.5)	4.7 (1.6-9.0)	4.7 (1.6-9.0)	16 (1-30)	30 (5-54)	43 (7-79)
Veery (*Catharus fuscescens*)	1.6 (0.1-4.6)	2.3 (0.4-5.5)	0.8 (0.0-4.1)	22 (0-57)	11 (0-22)	6 (0-16)
European Starling (*Sturnus vulgaris*)	9.4 (4.9-14.8)	8.6 (4.2-14.1)	9.4 (4.9-14.8)	26 (12-40)	102 (0-202)	89 (0-164)
Sprague's Pipit (*Anthus spragueii*)	3.9 (1.1-8.1)	5.5 (2.1-10.0)	6.3 (2.7-10.8)	15 (2-28)	29 (5-52)	42 (8-75)
Chestnut-sided Warbler (*Dendroica pensylvanica*)	0	0	1.6 (0.1-4.6)	0	0	4 (0-9)
Black-and-white Warbler (*Mniotilta varia*)	1.6 (0.1-4.6)	3.1 (0.8-6.5)	4.7 (1.6-9.0)	6 (0-13)	14 (0-27)	45 (0-86)
American Redstart (*Setophaga ruticilla*)	5.5 (2.1-10.0)	3.9 (1.1-8.1)	3.9 (1.1-8.1)	26 (0-51)	21 (4-39)	41 (0-76)
Ovenbird (*Seiurus aurocapillus*)	1.6 (0.1-4.6)	3.9 (1.1-8.1)	3.9 (1.1-8.1)	12 (0-25)	40 (0-77)	61 (0-131)

Continued

TABLE 1. *Concluded*

Species	Frequency of occurrence (CI)			Population estimate (CI)		
	1967	1992	1993	1967	1992	1993
Northern Waterthrush (*Seiurus noveboracensis*)	1.6 (0.1-4.6)	0	0	4 (0-9)	0	0
Mourning Warbler (*Oporornis philadelphia*)	0	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-6)	2 (0-6)
Yellow-breasted Chat (*Icteria virens*)	1.6 (0.1-4.6)	3.1 (0.8-6.5)	3.9 (1.1-8.1)	12 (0-26)	12 (1-23)	24 (4-43)
Brewer's Sparrow (*Spizella breweri*)	0.8 (0.0-4.1)	0.8 (0.0-4.1)	1.6 (0.1-4.6)	4 (0-11)	2 (0-5)	6 (0-14)
Field Sparrow (*Spizella pusilla*)	7.0 (3.2-11.9)	6.3 (2.7-10.8)	6.3 (2.7-10.8)	99 (41-156)	130 (29-231)	159 (47-270)
Le Conte's Sparrow (*Ammodramus leconteii*)	3.9 (1.1-8.1)	0.8 (0.0-4.1)	4.7 (1.6-9.0)	12 (2-22)	4 (0-12)	29 (0-58)
Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*)	2.3 (0.4-5.5)	2.3 (0.4-5.5)	7.0 (3.2-11.9)	7 (0-13)	7 (0-13)	27 (9-46)
McCown's Longspur (*Calcarius mccownii*)	3.1 (0.8-6.5)	0.8 (0.0-4.1)	0.8 (0.0-4.1)	50 (0-99)	4 (0-12)	2 (0-6)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	1.6 (0.1-4.6)	2.3 (0.4-5.5)	3.1 (0.8-6.5)	4 (0-9)	6 (0-12)	10 (1-20)
Black-headed Grosbeak (*Pheucticus melanocephalus*)	1.6 (0.1-4.6)	3.1 (0.8-6.5)	2.3 (0.4-5.5)	11 (0-26)	11 (1-21)	7 (0-13)
Blue Grosbeak (*Guiraca caerulea*)	0.8 (0.0-4.1)	0.8 (0.0-4.1)	0	2 (0-6)	2 (0-6)	0
Lazuli Bunting (*Passerina amoena*)	3.1 (0.8-6.5)	2.3 (0.4-5.5)	3.9 (1.1-8.1)	17 (0-33)	24 (0-52)	36 (0-70)
Indigo Bunting (*Passerina cyanea*)	1.6 (0.1-4.6)	1.6 (0.1-4.6)	1.6 (0.1-4.6)	4 (0-9)	4 (0-9)	6 (0-14)
Dickcissel (*Spiza americana*)	6.3 (2.7-10.8)	6.3 (2.7-10.8)	2.3 (0.4-5.5)	139 (26-252)	74 (7-14)	31 (0-75)
Spotted Towhee (*Pipilo maculatus*)	9.4 (4.9-14.8)	9.4 (4.9-14.8)	8.6 (4.2-14.1)	189 (64-314)	167 (58-275)	253 (84-423)
Eastern Meadowlark (*Sturnella magna*)	0	0	0.8 (0.0-4.1)	0	0	2 (0-6)
Bullock's Oriole (*Icterus bullockii*)	0	0	1.6 (0.1-4.6)	0	0	4 (0-9)
Pine Siskin (*Carduelis pinus*)	0	0	2.3 (0.4-5.5)	0	0	30 (0-75)

We estimated population means and totals, and their standard deviations, using standard methods for stratified random samples with proportional allocation (Cochran 1977). We calculated Bayesian confidence intervals (95% confidence limits, Box and Tiao 1973) in lieu of the usual confidence intervals. Bayesian intervals exploit the prior knowledge that the means of bird densities and frequencies of occurrence of birds are non-negative.

Vernacular and scientific names follow the American Ornithologists' Union (1998). The Red-shafted (*Colaptes auratus cafer*) and Yellow-shafted (*C. a. auratus*) subspecies of the Northern Flicker were recorded separately to reflect their treatment as separate species in 1967.

We classified each species into one of three groups according to its migration strategy: permanent resident (present in North Dakota year-round), short-distance migrant (winters primarily north of the U.S./Mexico border), and long-distance migrant (winters primarily south of the U.S./Mexico border; see Igl and Johnson 1997). In addition, we categorized each species into a general breeding habitat (Igl and Johnson 1997). Habitat classes were: wetland (including wet meadow), grassland, open habitat with scattered trees, woodland, open or semi-open deciduous woodland, shrubland, residential areas and human-made structures, and other habitat (mostly unvegetated habitats including clay buttes, cliffs, banks, rock outcrops, etc.). Chi-square tests of independence were conducted to test if the species status (i.e., common or uncommon) was independent of its migratory-strategy class or its breeding-habitat class.

Results and Discussion

The breeding avifauna of North Dakota is enriched by a diverse assemblage of birds with eastern, western, central, and boreal North American affinities (Stewart 1975). One hundred and sixty-one breeding bird species were observed within the 128 quarter-sections over the three years, including 129 species in 1967, 144 in 1992, and 153 in 1993 (Igl and Johnson 1997). Uncommon species are an important component of the avifaunal diversity of North Dakota; 92 (57%) species were classified as uncommon, with frequencies of occurrence of less than 10% in all years (Table 1; statewide population estimates in Table 1 are in 1000s of pairs). Sixty-one (47% of the total species) uncommon species were observed in 1967, 75 (52%) in 1992, and 84 (55%) in 1993. Fifty-four uncommon species occurred in all three years, 20 in only two years, and 18 in only one year. In addition, the Red-shafted subspecies of the Northern Flicker was considered uncommon each year, although its yellow-shafted counterpart was designated as common (Igl and Johnson 1997). We include the statewide frequency of occurrence and population estimate for the Red-shafted Flicker

TABLE 2. Composition of breeding birds in North Dakota, by migration strategy and habitat, in 1967, 1992, and 1993.

	Number of uncommon species	Number of common species
Migration strategy		
Long-distance migrant	32	30
Short-distance migrant[1]	53	33
Permanent resident	7	6
Breeding habitat		
Grassland	7	17
Open habitat/scattered trees	3	5
Wetland	34	17
Shrubland	7	7
Woodland	13	1
Open woodland/edge[1]	20	17
Residential/human structures	4	4
Other[2]	4	1
Total	92	69

[1]Northern Flicker counted only once in this category.
[2]Mostly unvegetated habitats including clay buttes, cliffs, banks, etc.

for each of the three years in Table 1, but the Northern Flicker, as a whole, would be considered common.

The estimated statewide populations of breeding birds in North Dakota were 25.5 million breeding pairs in 1967, 24.1 million in 1992, and 27.4 million in 1993 (Igl and Johnson 1997). Statewide population estimates are given in Table 1 for the 92 uncommon species. Uncommon species comprised 5% of the projected statewide breeding bird population in 1967 and 8% in both 1992 and 1993. In decreasing order, the five most abundant (averaged over the three years) uncommon species were Spotted Towhee (*Pipilo maculatus*), Field Sparrow (*Spizella pusilla*), Franklin's Gull (*Larus pipixcan*), Ruddy Duck (*Oxyura jamaicensis*), and Eared Grebe (*Podiceps nigricollis*) (Table 1).

The numbers of common and uncommon species did not differ significantly within migratory strategies ($\chi^2 = 1.54$, $P = 0.463$, df = 2), but differed significantly among breeding habitats ($\chi^2 = 19.78$, P = 0.006, df = 7; Table 2). In particular, most species associated with woodland habitat were uncommon, a high number of species associated with wetlands and "other" habitats were uncommon, and a high number of grassland species were common. These patterns, in part, reflect the availability and distribution of suitable breeding habitats in North Dakota (see Igl and Johnson 1997). That is, species with broad geographic or habitat distributions within North Dakota were more likely to be common during our survey, whereas species that are rare (e.g., Blue Grosbeak [*Guiraca caerulea*]), very local (e.g., Broad-winged Hawk [*Buteo platypterus*]), or restricted to unique or uncommon habitats (e.g., Rock Wren [*Salpinctes obsoletus*]) were less likely to be encountered and, thus, were uncommon (Stewart 1975). Colonial-nesting (e.g., Franklin's Gull, Eared Grebe) and nocturnal (e.g., most owls) species were more likely to be uncommon than common in our survey, which may reflect limitations in survey methodology or that these species cannot be adequately sampled from randomly sampled quarter-sections. Although biases and limitations associated with the bird survey were not quantified, Stewart and Kantrud (1972) suggested that woodland species may not have been adequately sampled by the survey methods. Nonetheless, efforts were made to minimize apparent biases in methodology through adjustments in census techniques (Stewart and Kantrud 1972; Igl and Johnson 1997).

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Documents Cited (marked * where cited)

Faanes, C. 1991. Abundance and diversity of breeding birds in Platte River habitats. Unpublished report, U.S. Fish and Wildlife Service, Region 6, Biodiversity Conference, Denver, Colorado.

Faanes, C., and **G. R. Lingle.** 1995. Breeding birds of the Platte River Valley of Nebraska. Unpublished report, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

Skeel, M. A., D. C. Duncan, and **S. K. Davis.** 1995. Abundance and distribution of Baird's Sparrows in Saskatchewan in 1994. Unpublished report, Saskatchewan Wetland Conservation Corporation, Saskatchewan, Canada. 13 pages.

Literature Cited

Ainley, D. G., W. J. Sydeman, S. A. Hatch, and **U. W. Wilson.** 1994. Seabird population trends along the west coast of North America: causes and extent of regional concordance. Pages 119–133 *in* A century of avifaunal change in western North America. *Edited by* J. R. Jehl, Jr., and N. K. Johnson. Studies in Avian Biology 15.

American Ornithologists' Union. 1998. Check-list of North American birds. Seventh edition. American Ornithologists' Union, Washington, D.C. 829 pages.

Box, G. E. P., and **G. C. Tiao.** 1973. Bayesian inference in statistical analysis. Addison-Wesley, Reading, Massachusetts. 588 pages.

Cochran, W. G. 1977. Sampling techniques. John Wiley and Sons, Inc., New York. 413 pages.

Forbes, S. A. 1913. The midsummer birdlife of Illinois: a statistical study. Illinois Laboratory of Natural History Bulletin 9: 373–385.

Forbes, S. A., and **A. O. Gross.** 1922. The numbers and local distribution in summer of Illinois land birds of the open country. Illinois Natural History Survey Bulletin 14: 187–218.

Forbes, S. A., and **A. O. Gross.** 1923. The numbers and local distribution of Illinois land birds of the open country in winter, spring, and fall. Illinois Natural History Survey Bulletin 14: 397–453.

Graber, R. R., and **J. W. Graber.** 1963. A comparative study of bird populations in Illinois, 1906-1909 and 1956-1958. Illinois Natural History Survey Bulletin 28: 383–528.

Haig, S. M., and **J. H. Plissner.** 1993. Distribution and abundance of Piping Plovers: results and implications of the 1991 international census. Condor 95: 145–156.

Houston, C. S., D. G. Smith, and **C. Rohner.** 1998. Great Horned Owl (*Bubo virginianus*). *In* The birds of North America, Number 372. *Edited by* A. Poole and F. Gill, The Birds of North America, Inc., Philadelphia, Pennsylvania.

Igl, L. D., and **D. H. Johnson.** 1997. Changes in breeding bird populations in North Dakota: 1967 to 1992-93. Auk 114: 74–92.

Page, G. W., and **R. E. Gill, Jr.** 1994. Shorebirds in western North America: late 1800s to late 1900s. Pages 147–160 *in* A century of avifaunal change in western North America. *Edited by* J. R. Jehl, Jr., and N. K. Johnson. Studies in Avian Biology 15.

Robbins, C. S., D. Bystrak, and **P. H. Geissler.** 1986. The Breeding Bird Survey: its first fifteen years, 1965-1979. U.S. Fish and Wildlife Service Resource Publication 157, Washington, D.C. 196 pages.

Stewart, R. E. 1975. Breeding birds of North Dakota. Tri-College Center for Environmental Studies, Fargo, North Dakota. 295 pages.

Stewart, R. E., and **H. A. Kantrud.** 1972. Population estimates of breeding birds in North Dakota. Auk 89: 766–788.

U.S. Fish and Wildlife Service. 1997. Waterfowl population status, 1997. Office of Migratory Bird Management, Branch of Surveys and Assessment, Laurel, Maryland. 32 pages.

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Status of Lyall's Mariposa Lily, *Calochortus lyallii* (Liliaceae), in Canada*

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Miller, Michael T., and George W. Douglas. 1999. Status of Lyall's Mariposa Lily, *Calochortus lyallii* (Liliaceae), in Canada. Canadian Field-Naturalist 113(4): 652–658.

In Canada, Lyall's Mariposa Lily, *Calochortus lyallii*, is confined to a single height of land in extreme southcentral British Columbia, where it occupies natural openings in Douglas-fir forest. The 11 known colonies in this upland area represent the northern range limit of the species, which is otherwise limited to the eastern slopes of the Cascade Mountains in Washington. Aside from gravity, *Calochortus lyallii* possesses no obvious mechanism for dispersing its seeds, a factor that may limit its ability to establish new populations at unoccupied sites. Nevertheless, *Calochortus lyallii* tends to be abundant where it occurs (median estimated patch size = 6500+ individuals), and colonies in British Columbia appear to be robust, both in terms of numbers of individuals and the proportion of new recruits present. However, recent silvicultural activities on Black Mountain, such as the introduction of forest tree seedlings into previously untreed *Calochortus lyallii* habitat, together with ongoing disturbances associated with livestock grazing (trampling, establishment of weedy exotics), now pose a serious potential threat to the persistence of *Calochortus lyallii* in Canada. It is suggested that the most effective way of safeguarding critical habitat for this species would be to safeguard the entire grass-forb community of which it is a part.

Key Words: Lyall's Mariposa Lily, *Calochortus lyallii*, threatened, distribution, fire, grazing, British Columbia.

Lyall's Mariposa Lily, *Calochortus lyallii*, is a member of a genus of about 60 species, all confined to western North America (Owenby 1940). It is one of three species occurring in British Columbia (Douglas et al. 1994) and in Canada (Scoggan 1978). *Calochortus lyallii* is not known to have any medicinal uses, although the bulbs of a related species, Sagebrush Mariposa Lily (*C. macrocarpus*), were harvested by native peoples of the Okanagan Valley, both for food and for the treatment of Poison-ivy blisters (Parish et al. 1996).

Calochortus lyallii is a perennial, tulip-like herb with one to 12 white or purplish-tinged, spreading flowers and a single long, flat basal leaf (Figure 1). The glabrous stem, which ranges from 10 to 20 cm tall, bears a bract-like leaf just below the inflorescence and one or more bract-like leaves subtending the flower stalks. Flowers are borne on slender erect stalks, have three petals, three sepals, and measure two to three cm across. The petals are broadly lanceolate, with fringed margins and a bearded, crescent-shaped gland toward the base. The sepals comprise a distinct series (they are narrower and greenish), a feature that sets this genus apart from most other groups in the Lily family. The fruit consists of an erect, glabrous, three-winged capsule.

Distribution

Calochortus lyallii occurs along the eastern front of the Cascade Mountains, from southcentral British Columbia southward to Yakima County, in southeastern Washington (Owenby 1940; Hitchcock and Cronquist 1973). In Canada, it is limited to the height of land — known locally as "East Chopaka" and including Black Mountain — that separates the Okanagan and Similkameen Valleys in extreme south central British Columbia, west of the town of Osoyoos and south of Richter Pass (Figure 2). All known sites occur within five km of one another and all are within five km of the U.S. border.

Habitat

Calochortus lyallii is endemic to the western Great Basin, a hot, arid region of sagebrush grasslands (shrub-steppe) and open coniferous forests occurring over portions of Washington, Idaho, Montana, and southcentral British Columbia. At the northern edge of its range in British Columbia, *Calochortus lyallii* inhabits natural openings in Douglas-fir (*Pseudotsuga menziesii*) forests at elevations ranging from 900–1300 m.

Typically grass-forb meadows, these sites contain a diverse plant community dominated by two species of bunch grass, Bluebunch Wheatgrass (*Elymus spicatus*) and Idaho Fescue (*Festuca idahoensis*). Other

*This is a Status Report of a species restricted in Canada to British Columbia. This report has not been submitted to, nor has status designation been made by, the National Committee on the Status of Endangered Species in Canada (COSEWIC).

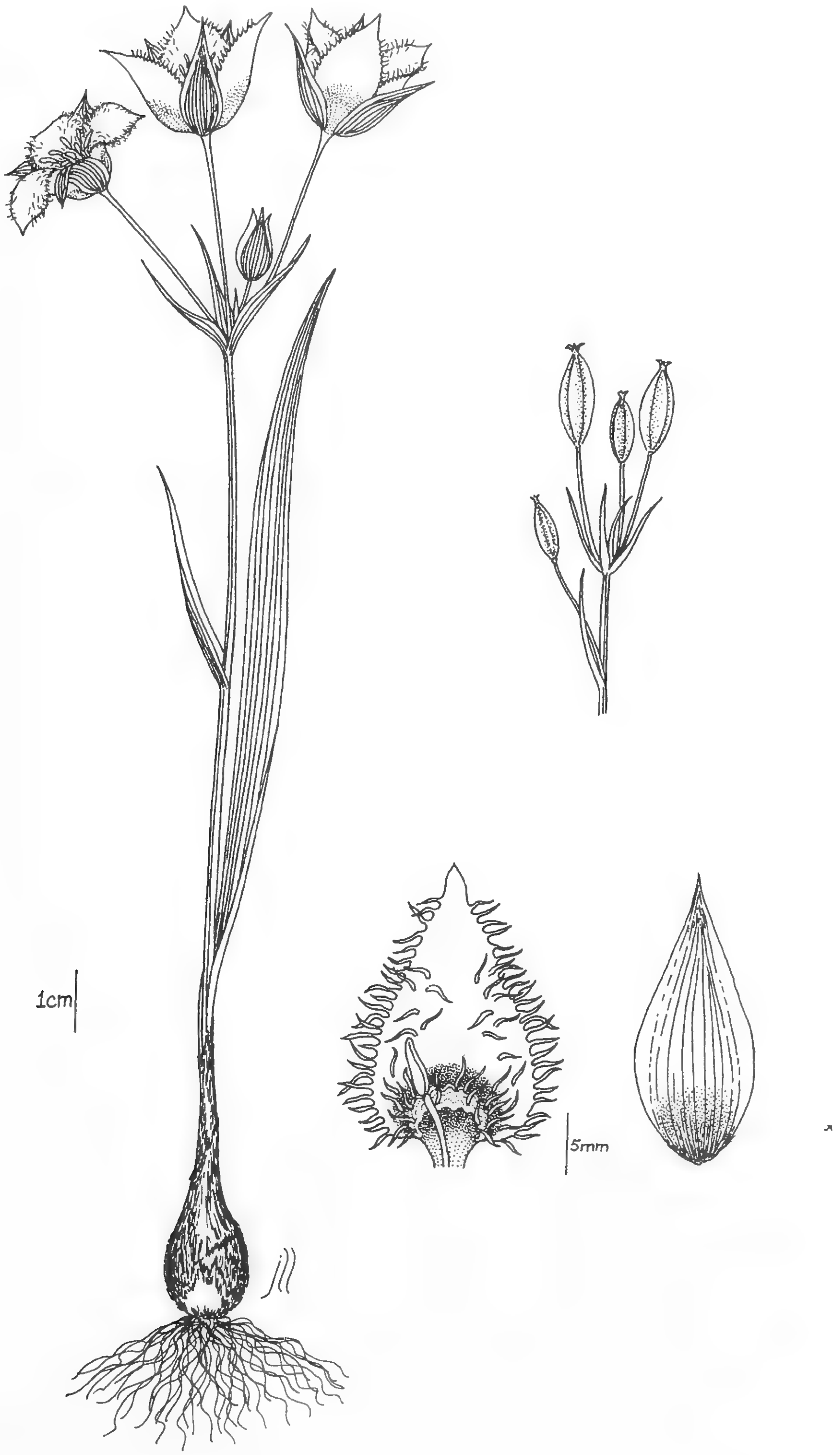

FIGURE 1. Illustration of *Calochortus lyallii* (Line drawing by Jane Lee Ling in Douglas [1998]).

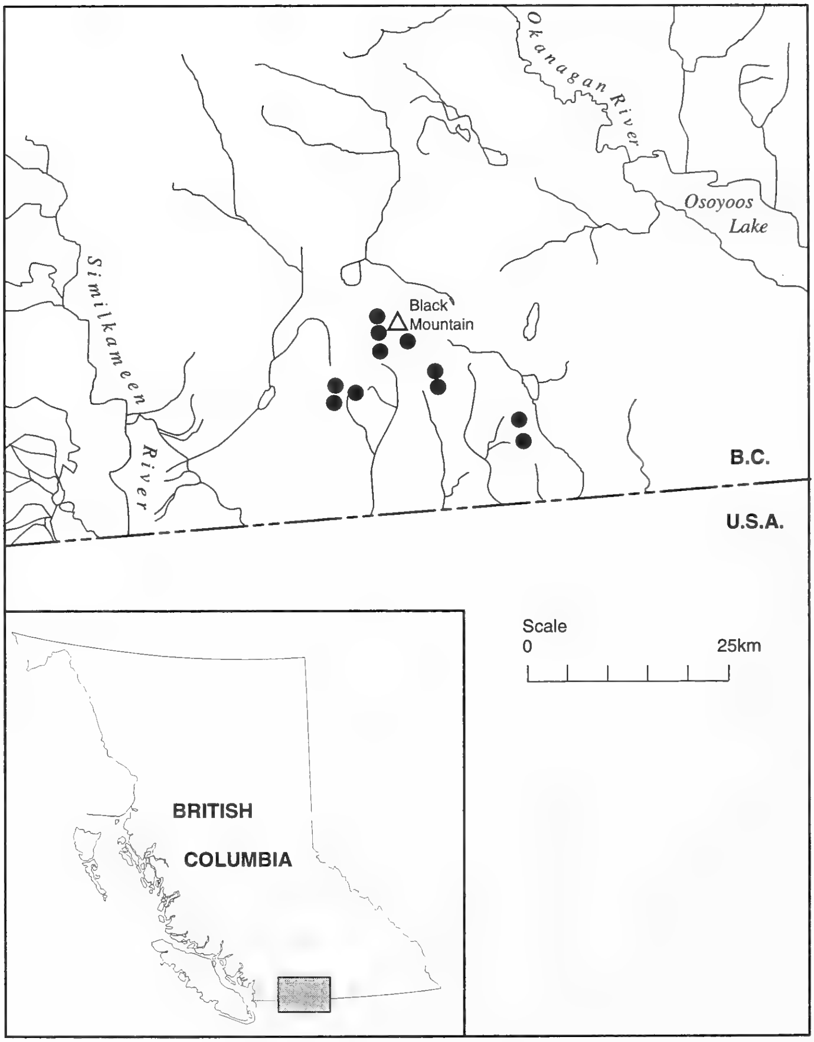

FIGURE 2. Distribution of *Calochortus lyallii* in British Columbia. (• - recently confirmed sites)

grasses commonly associated with *Calochortus lyallii* are Junegrass (*Koeleria micrantha*) and Pinegrass (*Calamagrostis rubescens*). Common forbs include Death Camass (*Zygadenus venonosus*), Yellow Bell (*Fritillaria pudica*), Arrowleaf Balsamroot (*Balsamorhiza sagittata*), Silky Lupine (*Lupinus sericeus*), and Blue-eyed Mary (*Collinsia parviflora*). On drier sites, Bitterroot (*Lewisia rediviva*) and Big Sagebrush (*Artemisia tridentata*) comprise part of the association. Shrub cover is generally sparse, but includes Birch-leaved Spiraea (*Spiraea betulifolia*), Squaw Currant (*Ribes cereum*), and Saskatoon-berry (*Amelanchier alnifolia*). A few invading/residual Douglas-fir trees are also present at most of the sites.

Many of these plants are indicator species for moderately dry to dry, water-shedding sites with shallow, nitrogen-medium soils (or, in the case of *Elymus spicatus*, extremely dry, nitrogen-rich soil), their occurrence tending to decrease with increasing elevation and precipitation (Klinka et al. 1989). Similar meadow associations are fairly common in the high country south of Richter Pass, and probably represent subclimax communities maintained in an early successional stage by periodic fires (Ecosystems Working Group 1995). As it happens, a wildfire swept through the study area in the summer of 1994, incinerating most of the surrounding forest but leaving the herb community largely intact. Given that *Calochortus lyallii* is relatively shade intolerant and does not grow under dense canopy, such disturbances may play an important role in maintaining sufficient open habitat for the species.

General Biology

A spring perennial, *Calochortus lyallii* emerges each year before the snows have completely melted (i.e., before the end of April in its British Columbia habitat) and is in flower by June. Seeds are released in July and germinate the following spring. seedlings emerge in late April and early May, shortly after the last snow has melted. The single seedling leaf (cotyledon) remains green for just a month or so before withering, at which point the young plant enters dormancy until the following year.

The perennating organ is a subterranean bulb, from which the single basal leaf and flowering stem (in reproductive plants) are annually renewed. The bulb begins as a tiny structure initiated during the plant's truncated first season, eventually descending to a depth of about 10 cm. No record of the life span of the bulb is available; however, preliminary estimates of longevity based on annual increments in basal leaf width suggest individuals of the species may live for 10 or more years (M. Miller, unpublished data).

Like all members of the genus *Calochortus*, *C. lyallii* is iteroparous; that is the individuals reproduce several times over the course of a lifetime. Although bulbifery (the production of new propagules from bulb offsets) has been documented in other *Calochortus* species (Fiedler 1987), asexual reproduction has not been observed in *Calochortus lyallii*. Instead, reproduction is exclusively by seed. Plants produce, on average, around 20 seeds per fruiting capsule. Seeds are gravity dispersed and tend to land close to the parent plant. Seed germination trials conducted *in situ* indicate that most seeds germinate successfully within the first year (M. Miller, unpublished data). The presence of a soil seed bank is therefore unlikely, which is consistent with findings for other liliaceous perennials (G. Allen, personal communication).

Plants must be of a certain size to reproduce, and usually do not begin to flower until they are three-four years old. In general, the larger the plant, the more flowers and fruits it will produce in a given year. However, not all adult plants flower or even increase in size every year. Many (up to 80% of the population) enter a vegetative state in which they produce a leaf but no flower stem; others remain reproductive but regress to a smaller size, initiating fewer flowers than the previous year. In other words, the demographic characteristics of individuals (such as fertility and survival rates) are more likely to be related to size, or stage, than to age, a phenomenon common to many perennial plant species (Werner and Caswell 1977; Fredricks 1992).

Population sizes and trends

As with a number of other taxa intensively inventoried by the British Columbia Conservation Data Centre (e.g., Douglas and Illingworth 1997; Douglas and Ryan 1998; Jamison and Douglas 1998; Penny and Douglas 1999), our information on *Calochortus lyalli* has markedly increased. The latter species is now known from 11 sites whereas previously it was known from only four sites.

The eleven known sites of *Calochortus lyallii* are all from the vicinity of Black Mountain (Table 1). Owenby (1940) refers to a single British Columbia collection (by J. Macoun in 1905) from "open hilltops near Similkameen River, 1050 m elevation." The exact location and status of this population are unknown. Ten of the remaining 11 sites were either resurveyed or discovered during the present study (Table 1). Because the earliest detailed record dates back only to 1978, it is not possible to evaluate the status of *Calochortus lyallii* populations in terms of historical trends. All that can be assessed is their presence or absence.

Calochortus lyallii tends to be very abundant where it occurs, often reaching densities in excess of 100 plants per m^2. Colonies range in area from 50 m^2

TABLE 1. Collection dates and population sizes for *Calochortus lyallii* in British Columbia.

Collection Site	Last Observation	Collector	Colony(number of stems/area)
Black Mountain:			
#1	1998	Miller	15 000+/0.3 ha
#2	1998	Miller	2500+/0.1 ha
#3	1998	Miller	400 000+/1.9 ha
#4	1998	Miller	6500+/0.3 ha
#5	1995	Furness	100+/100 m^2
#6	1998	Miller	7200+/0.15 ha
#7	1998	Miller	65 000+/0.5 ha
#8	1998	Miller	200+/400 m^2
#9	1998	Miller	39 000+/0.8 ha
Lone Pine Creek:			
#1	1997	Miller	1200+/400 m^2
#2	1997	Miller	40+/50 m^2

to two hectares and contain anywhere from 40 to upwards of half a million individuals (Table 1). Active recruitment of juveniles was observed at all sites visited in 1998, although flowering rates were significantly lower than in previous years (M. Miller, unpublished data), possibly reflecting the hot dry spring. Alternatively, individuals may still be experiencing the aftereffects of the 1994 forest fire on Black Mountain, the short-term significance of which for the population dynamics of *Calochortus lyallii* can only be guessed.

Limiting Factors

In Canada, *Calochortus lyallii* is confined to a single height of land in extreme southcentral British Columbia, where it occupies grassy openings in Douglas-fir forest. There does not appear to be a shortage of suitable habitat, at least locally, for this species. Aside from gravity, however, *Calochortus lyallii* possesses no obvious mechanism for dispersing its seeds, a factor that may limit its ability to establish new populations at unoccupied sites.

The major threat to *Calochortus lyallii* is likely habitat destruction. The great majority of known *Calochortus lyallii* populations occur on a single contiguous section of provincial Crown land encompassing the upper slopes of Black Mountain. This land is surrounded down slope by a matrix of private ranch holdings and is itself licensed both for grazing and timber extraction. Although cattle do not actively graze on *Calochortus lyallii*, mechanical damage due to trampling may have important consequences for local population dynamics. At one site, for example, where 17% of all flowering stems were trampled during the course of the 1996 flowering season, cattle visitation had a significant negative impact on the average per capita seed production of the population (M. Miller, unpublished data). Also of concern is the impact that soil compaction may have on seed germination rates and seedling survival as a consequence of changes both to surface soil structure and soil moisture status.

In 1995, salvage logging operations cleared away large sections of burnt out forest on the north and east slopes of Black Mountain, further facilitating livestock access to several *Calochortus lyallii* sites. In some places, clearcuts extend to within 100 m of *Calochortus lyallii* colonies, raising the additional spectre of invasions by weedy exotics. Already, a cocktail of troublesome weeds, including Canada Thistle (*Cirsium arvense*), Hound's Tongue (*Cynoglossum offincinale*), and Mullein (*Verbascum thapsus*) have gained a foothold in some areas, while at least one *Calochortus lyallii* site has been invaded by the weeds, Filago (*Filago arvensis*) and Prickly Lettuce (*Lactuca serriola*).

Ironically, it is not logging *per se*, but the replanting that was done following logging that has created the most direct threat to *Calochortus lyallii* habitat on Black Mountain. During the latter procedure, dozens of natural meadow openings, at least one of which contains a previously unrecorded colony of *Calochortus lyallii*, were targeted for reforestation and systematically planted with coniferous tree seedlings. A number of these seedlings were subsequently removed by hand, but many remain where they were placed. If permitted to grow, these introduced canopy species will almost certainly have an altering effect on the region's grassland-meadow system, which at present contains significant patches of potential *Calochortus lyallii* habitat.

The two Kilpoola Lake sites, which are situated on a private ranch lease 1.5 km south of Black Mountain, also display signs of recent disturbance. A logging road, blazed into the area to access burnt timber, passes within a few metres of both colonies, potentially exposing them to hazards from other forms of off-road, mechanized traffic. Immediate impacts of the logging itself are unclear, given that these sites were only recently "discovered" and their condition prior to logging unknown. However, their relatively small size as well as their isolation make these colonies especially vulnerable to disturbance, particularly since the ridge on which they occur comprises the most sparsely forested of all the *Calochortus lyallii* sites and is readily accessed by livestock.

Special Significance of the Species

Calochortus lyallii is taxonomically unique in British Columbia, being the only one of the three found in the province to belong to subsection *Nitidi*, a distinct group of species within the section *Eucalochortus* (Owenby 1940). The Similkameen River Valley separates British Columbia populations of *Calochortus lyallii* from the closest known Washington population 20-km to the south. Consequently, any further dispersal into Canada from this part of the range would have to be effected through the air. However, the very limited number of *Calochortus lyallii* occurrences north of the border suggests that colonization events of this type are quite rare. The significance of such peripheral populations, especially with respect to their genetic characteristics, has yet to be studied adequately. This species may prove to be a fruitful subject for genetic research.

Protection

There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The British Columbia Conservation Data Centre has ranked this species as S2 and placed it on the Ministry of Environment, Lands and Parks Red list (Douglas et al. 1998). This is the most critical category for imperiled rare native vascular plants in the province. The S2 rank is that of The Nature Conservancy, United States where S2 is considered "imperiled because of rarity (typically 6–20 extant occurrences or few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction."

In the remainder of its range, *Calochortus lyallii* is globally ranked as G3 by the United States Nature Conservancy, but has no separate state ranking in Washington. The G3 rank is considered "rare or uncommon (typically 21–100 occurrences); may be susceptible to large-scale disturbances; e.g., may have lost extensive peripheral populations."

Of the 11 known *Calochortus lyallii* sites, two occur on private land, the other nine on provincial Crown land. No particular strategy is in place to manage for the latter. Nonetheless, the British Columbia Ministry of Forests, which administers Crown land in the province, has acknowledged the need to preserve *Calochortus lyallii* habitat (Allan Vyse, personnel communication), and no further silvicultural activities are planned in the sites where it grows (but see Limiting Factors, above). At the same time, it appears that grazing pressure on Black Mountain, has, if anything, increased in recent years, as wandering livestock from local ranches take advantage of the flush of new growth created in the wake of the fire that swept through the area in 1994.

The hill range to which *Calochortus lyallii* is restricted forms part of a larger upland system that includes Mount Kobau, Kilpoola Lake, Chopaka, and the International Grasslands. This region has been recognized as an area of "exceptionally high natural diversity that is in danger of degradation and loss of habitat and associated wildlife, invertebrate and plant species" (Bryan 1996). Located at the northern extreme of the Western Great Basin ecosystem, the area hosts an inordinate proportion of the province's rarest species, including many found nowhere else in Canada. It also contains one of the largest remaining tracts of sagebrush grassland in the south Okanagan (Bryan 1996). In recognition of its unique character, the Mount Kobau/Kilpoola Lake/Chopaka region has recently been accorded "Goal one" Study Area status by the British Columbia government's Land Use Coordination Office (Kaaren Lewis, personnel communication). When management plans are in place, rare plants should receive a higher degree of protection than they previously have had. Until then, however, the existence of *Calochortus lyallii* in East Chopaka, together with the plant assemblage of which it is a part, will remain under some threat from the causes outlined above.

Evaluation of Status

Despite recent disturbances from silvicultural activities and ongoing disturbances associated with livestock grazing, there is no evidence at present to suggest that *Calochortus lyallii* is in decline or imminently at risk of extirpation. Individual colonies appear in general to be robust, both in terms of numbers of plants (median estimated patch size equals 6500 plus individuals) and the proportion of new recruits present. Although forest succession, both natural and human induced, poses a potential long-term threat to these colonies, the recent fire at East Chopaka has had the immediate effect of increasing the amount of open habitat in the area. Meanwhile, the same feature that helps to make *Calochortus lyallii* fire resistant—its bulbiferous habit—may also buffer the species against other short-term, above-ground disturbances such as trampling.

On the other hand, the level of perturbation that has been visited on Black Mountain in recent years is likely unprecedented in scale. Since 1995, the habitat there has been fragmented by three separate logging cut-blocks, each measuring several hectares, and further disturbed by the planting of trees in previously untreed meadows. At the same time, approximately 150 head of cattle continue to be turned out each spring to graze in the post-burn landscape, with uncertain consequences for the remaining habitat. Since these developments are so recent it is too early to assess their long-term impact on extant *Calochortus lyallii* populations, especially in the absence of historical information on population numbers. There is no benchmark against which to compare the present performance of the species. Regardless of present population status, only time may tell whether *Calochortus lyallii* has the ability to cope with such rapid changes to its habitat.

Calochortus lyallii is considered by the authors and the British Columbia Conservation Data Centre to be threatened in Canada. Its confined range, the close proximity of all known colonies to one another, and the small spatial extent of each patch combine to make this species highly vulnerable to disruption from both stochastic environmental events and human encroachment.

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Literature Cited

Bryan, A. 1996. Kilpoola-Kobau-Chopaka habitat management plan. British Columbia Ministry of Environment, Penticton. 103 pages.

Douglas, G. W., G. B. Straley, and **D. Meidinger**. 1994. The vascular plants of British Columbia. Part 4 - Monocotyledons. Special Report Series 4, British Columbia Ministry of Forests, Victoria. 257 pages.

Douglas, G. W., G. B. Straley, and **D. Meidinger**. 1998. Rare native vascular plants of British Columbia. British Columbia Ministry of Environment, Victoria. 423 pages.

Douglas, G. W., and **J. M. Illingworth**. 1997. Status of the White-top Aster, *Aster curtus* (Asteraceae) in Canada. Canadian Field-Naturalist 111: 622–627.

Douglas, G. W., and **M. Ryan**. 1998. Status of the Montane Yellow Violet, *Viola praemorsa* ssp. *praemorsa* (Violaceae) in Canada. Canadian Field-Naturalist 112: 491–495.

Ecosystems Working Group. 1995. Standards for terrestrial ecosystem mapping in British Columbia. Draft document, prepared for the Terrestrial Ecosystems Task Force. Resource Inventory Committee, Victoria.

Hitchcock, A., and **A. Cronquist**. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle. 730 pages.

Fiedler, P. L. 1987. Life history and population dynamics of rare and common mariposa lilies (*Calochortus* Pursh: Liliaceae). Journal of Ecology 75: 977–995.

Fredricks, N. 1992. Population biology of rare, serpentine endemic mariposa lilies (Calochortus: Liliaceae) from southwestern Oregon. Ph.D. dissertation, Oregon State University, Corvallis.

Jamison, J. A., and **G. W. Douglas**. 1998. Status of the Coastal Wood Fern, *Dryopteris arguta* (Dryopteridaceae) in Canada. Canadian Field-Naturalist 112: 284–288.

Klinka, K., V. H. Krajina, A. Ceska, and **A. M. Scagel**. 1989. Indicator plants of Coastal British Columbia. University of British Columbia Press, Vancouver. 288 pages.

Owenby, M. 1940. A monograph of the genus *Calochortus*. American Journal of Botany 27: 371–560.

Parish, R., R. Coupé and **D. Lloyd**. 1996. Plants of southern interior British Columbia. Lone Pine Publishing, Vancouver. 463 pages.

Penny, J. L, and **G. W. Douglas**. 1999. Status of Tall Bugbane, *Cimicifuga elata* (Ranunculaceae), in Canada. Canadian Field–Naturalist 113: 461–465.

Scoggan, H. J. 1978. The flora of Canada. Part 2-Pteridophyta, Gymnospermae, Monocotyledoneae. National Museum of Natural Sciences Publications in Botany Number 7. 545 pages.

Werner, P. A., and **H. Caswell**. 1977. Population growth rates and age versus stage distribution models for teasel. Ecology 58: 1103–1111.

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On the Taxonomic Disposition of the Whitlow-grass, *Draba ogilviensis* Hultén

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Murray, David F., and Carolyn L. Parker. 1999. On the taxonomic disposition of the whitlow-grass, *Draba ogilviensis* Hultén. Canadian Field-Naturalist 113(4): 659–662.

Draba ogilviensis is a species endemic to Alaska, Yukon, and Northwest Territories distinct from *D. sibirica* and *D. juvenilis* (=*D. longipes*), and not synonymous with *D. juvenilis* as proposed recently by Berkutenko.

Key Words: Whitlow-grass, *Draba ogilviensis*, *D. sibirica*, *D. juvenilis*, rare plants, Alaska, Yukon, Northwest Territories.

Berkutenko (1998) in her recent discussion of *Draba sibirica* (Pall.) Thell. has placed *D. ogilviensis* Hultén, *D. kananaskis* G. A. Mulligan, and *D. longipes* Raup in synonymy with *D. juvenilis* Komarov. We have known of her opinion for some time through papers and posters she has presented at conferences (cf. Berkutenko 1995) and from her, publications in Russian (Berkutenko 1983, 1997). With the exception of the status of *D. kananaskis,* with which we are unfamiliar, we have formulated an opinion regarding Berkutenko's conclusions.

Our interest in this taxonomic problem was stimulated by the collection (by C.L.P.) in 1996 of a stoloniferous, mat-forming, bright yellow *Draba* from mesic willow-dwarf shrub tundra, which we determined as *D. ogilviensis*. This was the first record for Alaska of this taxon (Figure 1) which was otherwise known only from the Ogilvie Mountains of adjacent Yukon Territory and the Mackenzie Mountains of westernmost Northwest Territories (see maps in Porsild and Cody 1980; Douglas et al. 1981; Cody 1996; and Lipkin and Murray 1997). As this collection came from the small portion of the Ogilvie Mountains extending into eastern interior of Alaska, this discovery was not unexpected. It did, however, raise for us the issue of which name from among several possibilities should be applied.

The taxon was first reported by Porsild (1964) from northwestern Yukon as *Draba sibirica*. Later, Hultén (1966) noted several differences among specimens he collected of the same taxon from along the Dempster Highway in the Yukon Territory, which he felt distinguished these plants from *D. sibirica* at the rank of species, and he applied the new name *D. ogilviensis* to these plants. To this Porsild (1967, 1974) responded with arguments in support of his belief that Hultén's material was not different from *D. sibirica*. Scoggan (1978) followed Porsild in his treatment. Whereas Porsild and Cody (1968) used the name *D. sibirica* in their checklist to the continental Northwest Territories, the volume (Porsild and Cody 1980) ultimately prepared from that checklist used the name *D. ogilviensis* with *D. sibirica* sensu Porsild as a synonym.

Böcher (1974) reviewed and illustrated well the morphological variation and geographic distribution of *D. sibirica* and distinguished northern (subsp. *arctica*) and southern (subsp. *sibirica*) races. Since he dealt with material from Asia and Greenland, he was unable to resolve the issue of the plants from Yukon debated by Porsild and Hultén, which he saw as a "problem". By not taking up the name *D. ogilviensis*, he appeared to side with the view of Porsild.

Nevertheless, Mulligan (1976), Porsild and Cody (1980), Rollins (1993), and Cody (1996) consistently used the name *D. ogilviensis*, and one might have thought the matter well settled, until Berkutenko (1998) questioned its status.

Draba sibirica is a stoloniferous, creeping, mat-forming, scapose, yellow-flowered plant, which was well illustrated by the drawing from Gelert provided by Porsild (1964) and by photographs in Böcher (1974). It is distinguished by a pubescence primarily of simple and *sessile*, forked (malpighian) trichomes on the lower stem and on leaf margins and frequently also on leaf surfaces.

Plants from Alaska and Yukon, determined as *D. ogilviensis* do not share these features of *D. sibirica* (Figure 2 in Hultén 1966 and Figure 2 and Table 1 herein). All of our material, including the type specimen of *D. ogilviensis* at S (!) and the isotype at DAO (!), are without malpighian hairs as was already noted by Mulligan (1976).

When reporting *D. sibirica*, Porsild (1964) wrote "By its matted habit, long, creeping stolons terminating in leafy rosettes, by its yellow flowers on naked peduncles and, above all, by its appressed, bifurcate (malpighiaceous) hairs. . . *D. sibirica* differs from all other arctic or boreal *Drabae*." It is not clear to us if, in this passage, he was describing the new material at hand, as we had thought upon first reading, or if he was simply describing *D. sibirica*. We now think the latter to be true. Also misleading was the illustration of *D. sibirica* (Figure 2, Porsild 1964), since one

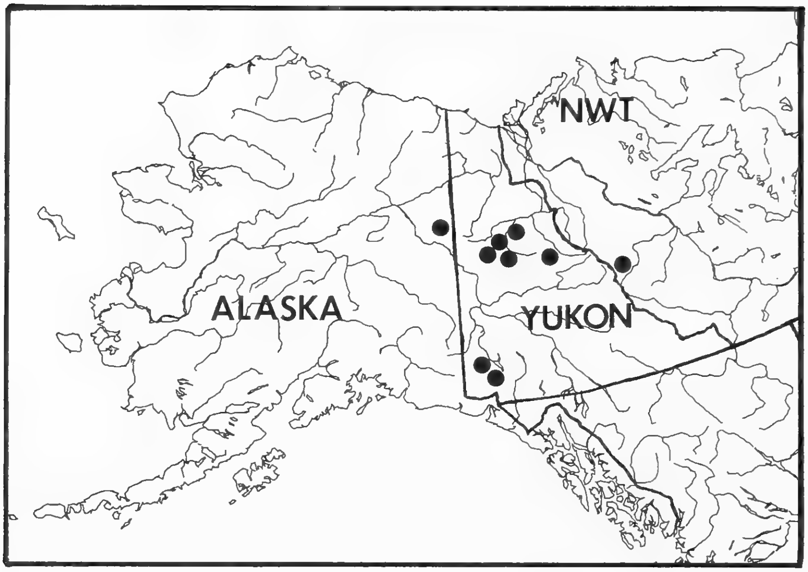

FIGURE 1. Distribution of *Draba ogilviensis* based on Cody (1996) and specimen records in the database of the Northern Plant Documentation Center (ALA).

would naturally believe that it was given because it matched the Yukon specimens in all respects. Not only does all material from Alaska, Yukon, and Northwest Territories lack the malpighian hairs but it also differs from *D. sibirica* by generally having one or a pair of stem leaves. Opposite or subopposite pairs of stem leaves are clearly shown in Figure 2 of the protologue for *D. ogilviensis* (Hultén 1966). Our material of *D. ogilviensis*, therefore, differs in at least two significant ways from *D. sibirica*.

The differences between *D. sibirica* and *D. ogilviensis* do not fall within the range of variation seen among individuals on a single mountain side over an altitudinal gradient of about 800 m as claimed by Porsild (1967, 1974). We have examined the specimens at ALA, CAN, DAO, O, and S and

TABLE 1. Comparison of diagnostic features for *Draba sibirica*, *D. ogilviensis*, and *D. juvenilis*.

	D. sibirica	*D. ogilviensis*	*D. juvenilis* (=*D. longipes*)
habit	loosely matted with long, slender, leafy branches	loosely matted with long, slender, leafy branches	densely to loosely tufted with slender branches
stem leaves	none	none or 1-2, as a subopposite pair; margins entire	none or 1-2 or exceptionally 3; alternate; margins frequently toothed
trichomes	simple and sessile, 2 forked (malpighian)	simple and stalked 2-forked, occasionally 3-forked	simple and stalked 2-3-forked and short stalked cruciform
flower color	yellow	yellow	white, cream, pale yellow
$2n=$	16	16	64
distribution	Siberia, Russian Far East, Greenland	Alaska, Yukon, Northwest Territories	Siberia, Russian, Far East, Alaska, Yukon, western Northwest Territories, northern British Columbia, western Alberta, south to Wyoming

FIGURE 2. Fruiting and flowering plants of *Draba ogilviensis*. Drawing by Dominique Collet.

therefore have been able to assess the range of geographic and ecological expression of *D. sibirica*. It is clear that, whether the plants are large or small, whether from the far north (subsp. *arctica*) or the south (subsp. *sibirica*), *D. sibirica* is consistently scapose and has sessile forked hairs on the leaf margins, even when the rest of the plant is glabrous. Those familiar with the circumscription of species of *Draba* recognize that these are not trivial distinctions.

After looking at specimens of *D. ogilviensis* from ALA, CAN, DAO, and S to gain a similar understanding of local and regional variation, we recognize plasticity of stature and habit. Stem leaves on small plants are obscure or sometimes are lacking. But these differences do not blur the principal discontinuity seen in the types of trichomes present. When specimens of *D. sibirica* from Asia or Greenland are put side by side with ones from Alaska and Yukon, it is clear that there is nothing in North America like true *D. sibirica*, and on this point we (and others cited above) are in complete agreement with one conclusion in Berkutenko (1997, 1998).

One of us (D.F.M.) has studied authentic material of *D. juvenilis* at LE. Both of us have examined a good series of specimens from Russia at ALA. We agree with the conclusion of Berkutenko (1983, 1997, 1998) that *D. juvenilis* is the prior name for what we in North America have called *D. longipes*.

The final question remains whether, as Berkutenko has asserted, *D. ogilviensis* and *D. juvenilis* (=*D. longipes*) are the same species. There are similarities, and some confusion may be the result of seeing specimens of *D. juvenilis* in collections that were misidentified as *D. ogilviensis*. Porsild (1974) pointed out that *D. ogilviensis* (his *D. sibirica*) often can be found with *D. juvenilis*. In fact, some of the specimens at S collected by Hultén from along the Dempster Highway and determined by him as *D. ogilviensis* are, in fact, *D. juvenilis*! Fortunately this mix up did not intrude into Hultén's protologue of *D. ogilviensis*, which contains only features of *D. ogilviensis*.

Berkutenko has annotated the type of *D. ogilviensis* at S, the isotype at DAO, and specimens of *D. ogilviensis* at ALA and DAO as *D. juvenilis*, and with these determinations we disagree. The type and all specimens of *D. ogilviensis* we have seen are distinct in having always bright yellow flowers, not white, cream or pale yellow, and simple and short-stalked forked trichomes, never the cruciform ones typical of and diagnostic for *D. juvenilis*. There are, indeed, stoloniferous plants of *D. juvenilis* but with a pubescence typical of that species, not of *D. ogilviensis*. It is not the flower color or habit or trichomes taken separately that distinguish the plants, but the combination of these characteristics that distinguishes each taxon (Table 1). Furthermore *D. ogilviensis* is a diploid, 2n=16, (Mulligan and Porsild 1969, as *D. sibirica*), and *D. juvenilis* is an octoploid, 2n=64 (Mulligan 1970), a important distinction noted but not commented upon by Berkutenko (1998).

In our opinion, the creeping, mat-forming yellow *Draba* from extreme northwestern North America is distinct from *D. juvenilis* and is best treated as a distinct species, *D. ogilviensis*. *Draba ogilviensis* is an endemic of Alaska, Yukon, and N.W.T. and of conservation concern, conforming to the Nature Conservancy ranking of rarity of G2G3: S1 for Alaska, S2 for Yukon, and S1 for Northwest Territories.

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We are grateful for help from curators at CAN, DAO, LE, O, and S.C.L.P. thanks the National Parks Service for supporting fieldwork that led to her discovery of *D. ogilviensis* in Alaska. Barbara Murray, G. A. Mulligan, and two anonymous reviewers suggested improvements we have incorporated.

Literature Cited

Berkutenko, A. N. 1983. Crucifers of the Kolyma Upland. Academy of Sciences, USSR. Vladivostok. 164 pages. [in Russian]

Berkutenko, A. N. 1995. Diversity of Cruciferae in Beringia: some taxonomic and nomenclatural revisions. Programme and Abstracts, page 32. VI International Symposium, IOPB, Tromsø, Norway.

Berkutenko, A. N. 1997. New data on the similarity of the floras of western and eastern Beringia (examples from the Cruciferae). Vestnik DVO RAN (Magadan) 2: 62–68. [in Russian]

Berkutenko, A. N. 1998. Does the Whitlow-grass *Draba sibirica* (Pall.) Thell. occur in North America? Canadian Field-Naturalist 112: 513–515.

Böcher, T. 1974. Variation and distribution pattern in *Draba sibirica* (Pall.) Thell. Botaniska Notiser 127: 317–327.

Cody, W. J. 1996. Flora of the Yukon Territory. NRC Research Press, Ottawa. 643 pages.

Douglas, G. W. , G. W. Argus, H. L. Dickson, and **D. F. Brunton.** 1981. The rare vascular plants of the Yukon. Syllogeus number 28: 1–61, plus maps.

Hultén, E. 1966. New species of *Arenaria* and *Draba* from Alaska and Yukon. Botaniska Notiser 119: 313–316.

Lipkin, R., and **D. F. Murray.** 1997. Alaska rare plant field guide. U.S. Department of Interior, Anchorage.

Mulligan, G. A. 1970. Cytotaxonomic studies of *Draba glabella* and its close allies in Canada and Alaska. Canadian Journal Botany 48: 1431–1437.

Mulligan, G. A. 1976. The genus *Draba* in Canada and Alaska: key and summary. Canadian Journal Botany 54: 1386–1393.

Mulligan, G. A., and **A. E. Porsild.** 1969. Chromosome numbers of some plants from the unglaciated central Yukon plateau, Canada. Canadian Journal Botany 47: 655–662.

Porsild, A. E. 1964. *Potentilla stipularis* L. and *Draba sibirica* (Pall.) Thell. new to North America. Canadian Field-Naturalist 78: 92–96.

Porsild, A. E. 1967. *Draba sibirica* (Pall.) Thell. in North America. Canadian Field-Naturalist 81: 165–168.

Porsild, A. E. 1974 (1975). Materials for a flora of central Yukon Territory. National Museum Natural Sciences, Publications in Botany Number 4 : 1–77.

Porsild, A. E., and **W. J. Cody.** 1968. Checklist of the vascular plants of continental Northwest Territories, Canada. Plant Research Institute, Canadian Department of Agriculture, Ottawa. 102 pages.

Porsild, A. E., and **W. J. Cody.** 1980. Vascular plants of continental Northwest Territories, Canada. National Museum of Natural Sciences, Ottawa. 667 pages.

Rollins, R. C. 1993. The Cruciferae of Continental North America. Stanford University Press, Stanford. 976 pages.

Scoggan, H. J. 1978. The Flora of Canada. Part 3. National Museum of Natural Sciences, Publications in Botany Number 7(3): 547–1115.

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Notes

Frogs Consumed by Whimbrels, *Numenius phaeopus*, on Breeding Grounds at Churchill, Manitoba

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Didyk, Andy S., and M. D. B. Burt. 1999. Frogs consumed by Whimbrels, *Numenius phaeopus*, on breeding grounds at Churchill, Manitoba. Canadian Field-Naturalist 113(4): 663–664.

The gizzards of three female Whimbrels collected on breeding grounds at Churchill, Manitoba, contained the bones of Wood Frogs. This is the first record of Whimbrels feeding on vertebrates of any kind in America.

Key Words: Whimbrel, *Numenius phaeopus*, diet, Wood Frog, *Rana sylvatica*, breeding, Manitoba.

The Whimbrel, *Numenius phaeopus*, breeds in America from western and northern Alaska east to the western side of Hudson Bay and James Bay (Johnsgard 1981). At Churchill, Manitoba, it nests in hummock-bog, sedge-meadow and dry heath tundra areas. Higher nesting density and complexity of habitat contributes to a higher nesting success in hummock-bog habitats (Skeel 1983).

Upon their arrival on the breeding grounds, Whimbrels feed on a variety of previous summer's berries including Black Crowberry, *Empetrum nigrum*, Bog Blueberry,*Vaccinium uliginosum*, Mountain Cranberry, *Vaccinium vitis-idaea*, and Bearberry, *Arctostaphylos* spp., before switching to insects, mainly Diptera, Hymenoptera and Coleoptera, as they become abundant. Until the new berry crop becomes available, Whimbrels may supplement their diet with gastropods and the flowers of ericaceous plants. Through the rest of the year, the diet consists of crabs and other crustaceans, bivalves, gastropods, polychaetes, insects, and ripening berries (Bent 1929; Phelps and Meyer de Schauensee 1978; Skeel and Mallory 1996).

The gizzards of Whimbrels collected for a parasitological study during the nesting period at Churchill, Manitoba (58°45′ N, 94°00′ W), in mid-June 1991 were casually examined for food items. They contained a variety of berries and seeds, flowers and other plant material, and insect and crustacean parts. However, three of 10 gizzards, all from female Whimbrels, contained what appeared to be bones of amphibians. The bones were sent to Canadian Museum of Nature in Ottawa, Ontario, where they were identified as being from the Wood Frog, *Rana sylvatica*. The quantity of bones recovered suggested that the Whimbrels had each consumed at least two Wood Frogs. The only other North American curlew species previously known to feed on amphibians was the Long-billed Curlew, *Numenius americanus* (Bent 1929 *in* Johnsgard 1981).

The Wood Frog is one of only two frog species found in the Churchill area. (Preston 1982; Cook 1984), the other being the much smaller Boreal Chorus Frog, *Pseudacris maculata* (nomenclature after Weller and Green 1997). Both species are associated with open ponds and wet tundra, especially during the breeding season (Russell and Bauer 1993). Though the calling dates of the two species overlap and vary somewhat from year to year, at Churchill, Wood Frogs call for a shorter period of time than Boreal Chorus Frogs (W. B. Preston, personal communication). It is not known whether Whimbrels rely on the calling of Wood Frogs to locate their prey although data provided by W. B. Preston suggest the breeding season for Wood Frogs would have been at or near an end by the dates the Whimbrels were collected.

This is the first record of Whimbrels from North America (*Numenius phaeopus hudsonicus* Latham) consuming vertebrates of any kind. Kumari (1958) reported finding the lizard *Lacerta vivipara* in stomachs of several breeding *N. p. phaeopus* (Linnaeus) in Estonia, the only other known instance of vertebrates being consumed by Whimbrels.

The discovery of amphibian bones in gizzards of female Whimbrels from Churchill, Manitoba, suggests these vertebrates may serve as a means of supplementing calcium intake when calcium demand is high for the production of eggs and bone growth. MacLean (1974) suggested as much for several calidrine sandpiper species in Alaska.

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Literature Cited

Bent, A. C. 1929. Life histories of North American shorebirds: part II. Smithsonian Institution, United States National Museum Bulletin 146, Washington, District of Columbia. 412 pages.

Cook, F. R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Natural Sciences, National Museums of Canada, Ottawa. 200 pages.

Kumari, E. 1958. [The food of waders in the peat bogs in Estonia]. Ornitoloogiline kogumik Tartu 1: 195–215.

Johnsgard, P. A. 1981. The plovers, sandpipers and snipes of the world. University of Nebraska Press, Lincoln and London. 493 pages.

MacLean, S. F., Jr. 1974. Lemming bones as a source of calcium for arctic sandpipers (*Calidris* spp.). Ibis 116: 552–557.

Phelps, W. H., Jr., and **R. Meyer de Schauensee.** 1978. Aves de Venezuela. Princeton University Press, Princeton, New Jersey. 484 pages.

Preston, W. B. 1982. The amphibians and reptiles of Manitoba. Manitoba Museum of Man and Nature, Winnipeg, Manitoba.

Russell, A. P., and **A. M. Bauer.** 1993. The amphibians and reptiles of Alberta: a field guide and primer of boreal herpetology. University of Calgary Press, Calgary and University of Alberta Press, Edmonton. 264 pages.

Skeel, M. A. 1983. Nesting success, philopatry, and nest-site selection of the Whimbrel (*Numenius phaeopus*) in different habitats. Canadian Journal of Zoology 61: 218–225.

Skeel, M. A., and **E. P. Mallory.** 1996. Whimbrel (*Numenius phaeopus*). *In* The Birds of North America, Number 219. *Edited by* A. Poole and F. Gill. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, District of Columbia. 28 pages.

Weller, W. F., and **D. M. Green.** 1997. Checklist and current status of Canadian amphibians. Pages 309–328 *in* Amphibians in decline. *Edited by* D. M. Green. Herpetological Conservation Number One, Society for the Study of Amphibians and Reptiles, St. Louis, Missouri.

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Red Squirrel, *Tamiasciurus hudsonicus*, Population Density in the Southern Appalachian Mountains

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Stevens, Richard T., and Michael L. Kennedy. 1999. Red Squirrel, *Tamiasciurus hudsonicus*, population density in the southern Appalachian Mountains. Canadian Field-Naturalist 113(4): 664–667.

Population density of Red Squirrels (*Tamiasciurus hudsonicus*) was estimated at a mixed conifer-hardwood forest in the southern Appalachian Mountains of eastern Tennessee during three seasons (winter 1996, spring 1996, and winter 1997) from mark-recapture data using a modified Lincoln-Peterson estimator and program CAPTURE. Density was estimated at 1.30 squirrels/ha and 1.53 squirrels/ha using Lincoln-Peterson and program CAPTURE, respectively, during both winter 1996 and spring 1996. No squirrels were captured in winter 1997. Winter and spring 1996 density estimates approached those reported for Red Squirrel populations in boreal spruce (*Picea* sp.) forest, which is regarded as optimal habitat. The cause of the population decline between spring 1996 and winter 1997 was unknown.

Key Words: Red Squirrel, *Tamiasciurus hudsonicus*, population density, Tennessee, southern Appalachian Mountains.

The Red Squirrel (*Tamiasciurus hudsonicus*) is found throughout northern North America, and along the Appalachian Mountains south to Georgia and along the Rocky Mountains south to New Mexico (Flyger and Gates 1982). Throughout the range of the species, Red Squirrels prefer coniferous forest, especially spruce (*Picea* sp.)-fir (*Abies* sp.) forest, but are also found in conifer-hardwood mixtures and pure hardwood forest (Kemp and Keith 1970; Rusch and Reeder 1978; Flyger and Gates 1982). While there have been numerous studies of Red Squirrel ecology in coniferous forests of northern North America (C. Smith 1968; Rusch and Reeder 1978; Price et al. 1990; Larsen and Boutin 1994; Larsen and Boutin 1995; Stuart-Smith and Boutin 1995; Hurly and Lourie 1997), there have been relatively few studies of Red Squirrels in conifer-hardwood mixtures or in hardwood habitats, especially in southern parts of their range (Yahner 1987). Previous studies of Red Squirrels have found significant differences in densities among habitat types (Davis 1969; Kemp and Keith 1970; Rusch and Reeder 1978). Because of differences among habitats and because of potential competition for food and den sites with Gray Squirrels (*Sciurus carolinensis*), density estimates in the southern Appalachians could be lower than those in northern parts of the species range. The purpose of our study was to provide an estimate of Red Squirrel abundance in the southern Appalachians.

Materials and Methods

The study was conducted in the Falls Branch (35°22′ N, 84°07′ W) area of the Cherokee National Forest (CNF) near Tellico Plains, Monroe County, Tennessee. Overstory was composed primarily of mature Carolina Silverbell (*Halesia carolina*) and Eastern Hemlock (*Tsuga canadensis*) with a smaller proportion of Oak (*Quercus* sp.) and Hickory (*Carya* sp.). Dense thickets of Rhododendron (*Rhododendron* sp.) and Mountain Laurel (*Kalmia latifolia*) were interspersed throughout the understory. Elevation was approximately 1220 m.

A 5 × 10 trapping grid with 30 m between traps was established in December 1995. Trapping was conducted for 14 days (not consecutively) during each of the following seasons: winter 1996 (December 1995–February 1996), spring 1996 (March 1996–May 1996), and winter 1997 (December 1996–February 1997). Traps (15 × 15 × 61 cm Tomahawk live traps, Tomahawk Live Trap Company, Tomahawk, Wisconsin) were baited with peanut butter and sunflower seeds at dawn and checked 6–7 hours later. Captured Red Squirrels were forced into a laboratory animal restraint (Yahner and Mahan 1992) using a cloth funnel. Monel ear tags (National Band and Tag Company, Newport, Kentucky) were attached to both ears, and sex-age class (juvenile or adult) was determined (Kemp and Keith 1970). Squirrels were transferred to a cloth bag, weighed to the nearest 0.5 g using a spring balance, and released at the site of capture.

Population size was estimated from mark-recapture data using a modified Lincoln-Peterson estimator as described by Menkins and Anderson (1988) as well as by program CAPTURE (Otis et al. 1978). A 45 m strip, which was approximately half the diameter of average home range size (Larsen and Boutin 1994), was added to the perimeter of the grid to account for the total area of effect. Density was then determined by dividing the estimated population size by total area of effect (8.5 ha).

Results and Discussion

Eight individual Red Squirrels were captured 14 times during winter 1996, and nine individual Red Squirrels were captured 20 times during spring 1996. No squirrels were captured during winter 1997, and, therefore, the population size was estimated as 0.0 squirrels during this season. Population density estimates for winter 1996 and spring 1996 were relatively similar for Lincoln-Peterson and program CAPTURE (Table 1).

Of the two estimators, Lincoln-Peterson may have provided the more accurate estimate. Menkens and Anderson (1988) concluded that program CAPTURE performed poorly when sample sizes were small as in this study, and that under many conditions Lincoln-Peterson provided a better estimate of population size.

Judging from estimates elsewhere, density was relatively high at Falls Branch during spring 1996 and winter 1996. While direct comparisons of our results with others were imperfect due to a lack of standard methodology, density at Falls Branch was nearly as high as densities reported in boreal Spruce forest, which was considered optimal habitat for Red Squirrels (C. C. Smith 1968; Kemp and Keith 1970; Rusch and Reeder 1978; Yahner 1987). Densities in a White Spruce (*Picea glauca*) forest in the Yukon varied from 1.5–2.7 squirrels/ha (Price 1994; Price and Boutin 1993; Stuart-Smith and Boutin 1995). Davis (1969) found densities of 2.3 squirrels/ha in White Spruce forest in Alaska and 0.4 /ha in mixed pine and Black Spruce (*Picea mariana*) forests. The highest reported densities were those of Rusch and

TABLE 1. Population density estimates (number of animals/ha) of a Red Squirrel population in eastern Tennessee in 1996 using a Lincoln-Peterson estimator[1] and program CAPTURE[2]

Season	Lincoln-Peterson	95% C.I.	Program CAPTURE	95% C.I
Winter 1996	1.30	0.58–11.76	1.53	1.05–3.64
Spring 1996	1.30	0.94–2.94	1.53	1.18–3.76

[1]Modified Lincoln-Peterson estimator of Menkens and Anderson (1988).
[2]Heterogeneity model, M(h), which accounts for heterogeneous trap response (Otis et al. 1978).

Reeder (1978) who found approximately 5.0 squirrels/ha during winter and spring of two years in Spruce forest of Alberta. Red Squirrel densities in deciduous habitats are typically lower than those in coniferous habitats. Rusch and Reeder (1978) found densities in aspen (*Populus tremuloides*) habitat ranged between 0–0.99 squirrels/ha, and Bole (1939) reported a density of 0.69 squirrels/ha in a mature beech (*Fagus grandifolia*) and maple (*Acer* sp.) forest. The density of Red Squirrels at Falls Branch indicated that Silverbell-Hemlock habitat of the southern Appalachians was capable of supporting relatively high densities of Red Squirrels at least for short periods of time. However, whether these densities were abnormally high or indicated a peak in a population cycle was unknown.

The population density at Falls Branch dropped dramatically between spring 1996 and winter 1997. The cause of this decline was unknown. C. Smith (1968), M. Smith (1968), and Kemp and Keith (1970) noted Red Squirrel populations were cyclic in Spruce forests of Canada, presumably due to fluctuations in cone crops. However, Rusch and Reeder (1978) noted little fluctuation in population size among years at spruce and Jack Pine (*Pinus banksiana*) dominated stands, in Alberta. Food habits were not quantified at Falls Branch, but Squirrels were observed eating Hemlock cones, acorns, and Hickory nuts and were regularly seen eating Carolina Silverbell fruit. Mast crops have been surveyed annually in CNF (Tennessee Wildlife Resources Agency 1997), and 1996 was classified as a fair mast year overall (3.89 on a scale from 0 to 10). However, White Oak crops and Beech crops were rated fairly high (6.35 and 7.00, respectively). Thus, it did not appear that food supply was limited before the population decline.

Competition with other sciurids was not a likely cause of the decline. Only two Gray Squirrel sightings were recorded at Falls Branch during the course of the study, while >100 sightings of Red Squirrels were recorded.

Data collected as part of a concurrent study indicated that the population declined steadily between September 1996 and February 1997. A 1.5 km transect was walked at Falls Branch monthly between June 1996 and May 1997 and all Red Squirrels seen or heard calling were recorded. The highest number of squirrels counted was 13 during September 1996 (the mean number counted per month was 3.75). The number recorded had dropped to four by December 1996, and no squirrels were recorded between February 1997 and the end of the study in May 1997. This data supports the conclusion that the population had indeed declined and that squirrels were not simply avoiding traps.

The transect was walked again on 12 January 1999, and four Red Squirrels were counted. This provides evidence that the population had rebounded at least to some extent.

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Literature Cited

Bole, B. P. 1939. The quadrat method of studying small mammal populations. Cleveland Museum of Natural History Scientific Publication 5: 15–77.

Davis, D. W. 1969. The behavior and population dynamics of the red squirrel (*Tamiasciurus hudsonicus*) in Saskatchewan. Ph.D. dissertation. University of Arkansas, Fayettville, Arkansas. 233 pages.

Flyger, V., and **J. E. Gates.** 1982. Pine squirrels. Pages 230–238 *in* Wild mammals of North America: Biology, management, and economics. *Edited by* J. A. Chapman, and G. E. Feldhamer. The Johns Hopkins University Press. Baltimore, Maryland. 1147 pages.

Hurley, T. A., and **S. A. Lourie.** 1997. Scatterhoarding and larderhoarding by red squirrels: size, dispersion, and allocation of hoards. Journal of Mammalogy 78: 529–537.

Kemp, G. A., and **L. B. Keith.** 1970. Dynamics and regulation of red squirrel (*Tamiasciurus hudsonicus*) populations. Ecology 51: 763–779.

Larsen, K. W., and **S. Boutin.** 1994. Movements, survival, and settlement of red squirrel (*Tamiasciurus hudsonicus*) offspring. Ecology 75: 214–223.

Larsen, K. W., and **S. Boutin.** 1995. Exploring territory quality in the North American red squirrel through removal experiments. Canadian Journal of Zoology 73: 1115–1122.

Menkins, G. E., Jr., and **S. H. Anderson.** 1988. Estimation of small-mammal population size. Ecology 69: 1952–1959.

Otis, D. L., K. P. Burnham, G. C. White, and **D. R. Anderson.** 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62. 135 pages.

Price, K. 1994. Center-edge effect in red squirrels: Evidence from playback experiments. Journal of Mammalogy 75: 545–548.

Price, K., and **S. Boutin.** 1993. Territorial bequethal by red squirrel mothers. Behavioral Ecology 4: 144–150.

Price, K., S. Boutin, and **R. Ydenberg.** 1990. Intensity of territorial defense in red squirrels: an experimental test of the asymmetric war of attrition. Behavioral Ecology and Sociobiology 27: 217–222.

Rusch, D. A., and **W. G. Reeder.** 1978. Population ecology of Alberta red squirrels. Ecology 59: 400–420.

Smith, C. C. 1968. The adaptive nature of social organization in the genus of three squirrels *Tamiasciurus*. Ecological Monographs 38: 31–63.

Smith, M. C. 1968. Red squirrel responses to spruce cone failure in interior Alaska. Journal of Wildlife Management 32: 305–317.

Stuart-Smith, A. K., and **S. Boutin.** 1995. Predation on red squirrels during a snowshoe hare decline. Canadian Journal of Zoology 73: 713–722.

Tennessee Wildlife Resources Agency. 1997. Big game harvest report, 1996–1997. Technical Report Number 97-2. Nashville, Tennessee. 235 pages.

Yahner, R. H. 1987. Feeding-site use by red squirrels, *Tamiasciurus hudsonicus*, in a marginal habitat in Pennsylvania. Canadian Field-Naturalist 101: 586–589.

Yahner, R. H., and **C. G. Mahan.** 1992. Use of a laboratory restraining device on wild red squirrels. Wildlife Society Bulletin 20: 399–401.

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Range Extensions for Some Pacific Coast Sea Stars (Echinodermata: Asteroidea)

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Lambert, Philip. 1999. Range extensions for some Pacific coast sea stars (Echinodermata: Asteroidea). Canadian Field-Naturalist 113(4): 667–669.

Based on museum specimens, the known northern limit of three species of sea stars is extended north to localities in the Gulf of Alaska. The maximum depth limit of six species and the minimum depth limit of eight species are also extended.

Key Words: Asteroidea, sea stars, geographic range, depth range, Pacific Ocean.

Fisher (1911) noted that "... the west coast of North America is more prolific in species [of Asteroidea] and individuals than any other portion of the world." He recorded 143 species of sea stars (Asteroidea) from the shore to a depth of 2260 fathoms between San Diego, California, and Point Barrow, Alaska. Present knowledge indicates that the Indo-Pacific may have a more diverse sea star fauna (Mah 1998) but the west coast is certainly the richest in temperate waters. In British Columbia 69 species are known (Lambert 1981), 36 of these occuring in less than 200 metres. Most sea stars are carnivorous and play an important role as predators in the marine ecology of the region. The most important taxonomic work for asteroids of the west coast of North America is Fisher (1911, 1928, 1930). Verrill (1914) also contributed significant new information. Since 1930 some range extensions have been added (Alton 1966; D'Yakonov 1950; Hopkins and Crozier 1966; Lambert 1978b) but no new species have been described. However, recent DNA work by Foltz and his colleagues (Foltz 1998) has revealed eleven genetically distinct forms of the small Six-armed Star, *Leptasterias* which are potential new species.

While preparing a revision of *The Sea Stars of British Columbia* (Lambert 1981), I discovered some new records in the collections of the University of Alaska Museum, Fairbanks (UAF), Auke Bay Marine Lab (AB), Royal British Columbia Museum (RBCM), and the California Academy of Sciences (CASIZ). The new records reported here include three northern range extensions and fourteen revisions to known depth ranges. Species are listed alphabetically by genus. Each entry includes the new range, previous known range, the museum catalogue or collection number followed by the number of specimens in parentheses, the locality, the depth in metres, the collector and date. Other specimens that extend the range are briefly summarized. All species in this paper are described and illustrated in Lambert (1981). Classification follows Clark (1989, 1993, 1996).

Extensions to the northern geographic limit

Luidia foliolata Grube, 1866
[Family Luidiidae]
New geographic range: Cook Inlet, Alaska to Nicaragua.
Previous range: Southeastern Alaska to Nicaragua; 4–245 m (Clark 1989).
Material: CASIZ 17087 (1), Cook Inlet, Alaska (58°58.7′ N, 152°47.6′ W), 183 m, collected by Miller Freeman, 27 Oct 1976.

Poraniopsis inflatus inflatus (Fisher, 1906)
[Family Poraniidae]
New geographic range: Gulf of Alaska to San Diego, California.
Previous range: Dixon Entrance to San Diego, California (Lambert 1978b).
Material: Uncatalogued lot at UAF (1), Gulf of Alaska (59°39′ W 144°34′ N), 146 m estimated

from the chart, collector unknown, 1975. Four other lots off Yakutat Bay, Alaska: AB84-045 (1), AB93-021 (1), AB96-012 (2) and CASIZ 20250 (1) and one uncatalogued lot off Chichagof Island, Southeast Alaska: UAF (2).

Stylasterias forreri (de Loriol, 1887)
[Family Asteriidae]
New geographic range: Kodiak Island, Alaska to San Diego, California.
Previous range: Southeast Alaska to San Diego (Fisher 1928).
Material: CASIZ 18291 (1), western Kodiak Island (56°46′ N, 154°9.6′ W), 29 m, collected by ?"Big Valley", 21 June 1976. Seven other lots collected in the Gulf of Alaska: CASIZ 16835 (1), CASIZ 16863 (1), CASIZ 20241 (1), three lots UAF (3), and RBCM 977-443-1 (3).

Depth range extensions

Ceramaster patagonicus (Sladen, 1889)
[Family Goniasteridae]
New depth range: 10 to 540 m.
Previous range: 10 (Lambert 1981) to 245 m (Fisher 1911).
Material: RBCM 983-01396-2 (1), Jervis Inlet, B.C. (49°N, 124°W), 540 m, collected by Maria Byrne, 9 Oct 1982. Five other lots collected deeper than 245 m: RBCM 977-00421-3 (1), 360 m; CASIZ 19981 (1), 252 m; CASIZ 20087 (1), 323 m; CASIZ 19991 (1), 409 m; and CASIZ 20007 (1), 409 m.

Crossaster borealis Fisher, 1906
[Family Solasteridae]
New depth range: 161 to 1910 m.
Previous range: 320 to 1910 m (Clark 1996).
Material: Two uncatalogued lots (UAF) (4), Gulf of Alaska (59°21′ N, 140°14′ W), 161 m, collector unknown, 5 June 1975. Three other lots shallower than 320 m: CASIZ 19978 (1), 252 m; 2 lots UAF (2), 298 m and 284 m.

Diplopteraster multipes (Sars, 1865)
[Family Pterasteridae]
New depth range: 66 to 1225 m.
Previous range: 91 to 1225 m (Clark 1996).
Material: RBCM 63-00127 (1), Satellite Channel, southern B.C. (48°42.1′ N, 123°26.06′ W), 66 m, collected by Derek Ellis, 28 Oct 1965.

Dipsacaster anoplus Fisher, 1910
[Family Astropectinidae]
New depth range: 146 to 2200 m.
Previous range: 362 (Alton 1966) to 2200 m (Clark 1989).
Material: UAF NEGOA 1990-123 (1), off Yakutat Bay, Alaska (58°38′ N, 139°03′ W), 146 m, collector unknown, 6 Nov 1979. One other lot shallower than 362 m: RBCM 977-00298-1 (1), 340 m.

Dipsacaster borealis Fisher, 1910
[Family Astropectinidae]
New depth range: 200 to 642 m.
Previous range: 221 to 642 m (Clark 1989).
Material: AB96-11 (1), off Baranof Island, Southeast Alaska, (57°19.7′ N, 136°19.5′ W) and AB96-13 (1)(57 17.1′ N, 136 17.1′ W), both at 200 m, collected by Bruce Wing, 5 Aug 1996.

Evasterias troschelii (Stimpson, 1862)
[Family Asteriidae]
New depth range: Intertidal to 75 m.
Previous range: Intertidal to 71 m (Fisher 1930).
Material: CASIZ 16836 (1), Afognak Island, near Kodiak Island (58°8.2′ N, 152°9.5′ W), 75 m, collected by Yankee Clipper, 11 May 1978.

Lophaster furcilliger vexator Fisher, 1910
[Family Solasteridae]
New depth range: 12 to 670 m.
Previous range: 21 (Lambert 1978b) to 670 m (D'Yakonov 1950).
Material: RBCM 976-01045-3 (1), Barkley Sound, B.C. (48°48.1′ N, 125°10.1′ W), 12 m, collected by Phil Lambert, 14 July 1976.

Cheiraster (Luidiaster) dawsoni (Verrill, 1880)
[Family Benthopectinidae]
New depth range: 73 to 436 m.
Previous range: 73 (Lambert 1978a) to 384 m (Alton 1966).
Material: RBCM 974-167-4 (1), west of Barkley Sound (48°44.08′ N, 126°30.05′ W), 436 m, collected by Fisheries Research Board of Canada, Sept 1968.

Nearchaster aciculosus (Fisher, 1910)
[Family Benthopectinidae]
New depth range: 84 to 1460 m.
Previous range: 550 to 1460 m (Clark 1989).
Material: UAF Sta. 89E Haul 96 (1), Gulf of Alaska (59°51′ N, 142°3′ W), 84 m, collector unknown, 9 July 1975. One other lot shallower than 549 m: RBCM 974-306-2 (2), 229 m.

Nearchaster variabilis variabilis (Fisher, 1910)
[Family Benthopectinidae]
New depth range: 200 to 1061 m.
Previous range: 200 to 640 m (Clark 1989).
Material: RBCM 977-282-4 (3), off Cape St. James (52°5.08′N, 131°26.1′ W), 1061 m, collected by Frank Bernard, Sept 1971. One other lot deeper than 640 m: RBCM 974-193-5 (16), 924 m.

Orthasterias koehleri (de Loriol, 1897)
[Family Asteriidae]
New depth range: Intertidal to 256 m.
Previous range: Intertidal to 229 m (Fisher 1930).
Material: RBCM 988-16-35 (1), Caamano Sound, B.C. (52°54.68′ N, 129°19.67′ W), 256 m, collected by Phil Lambert, 26 Jan 1988.

Pisaster brevispinus (Stimpson, 1857)
[Family Asteriidae]
New depth range: Intertidal to 128 m.
Previous range: Intertidal to 102 m (Fisher 1930).
Material: RBCM 985-546-6 (1), Hecate Strait (54°18.1′ N, 131°23.08′ W), 128 m, collected by Doug Moore, 13 June 1985.

Poraniopsis inflatus inflatus (Fisher, 1906)
[Family Poraniidae]
New depth range: 8 to 366 m.
Previous range: 11 to 366 m (Lambert 1978b).
Material: RBCM 976-1077-12 (1), Tasu Sound, B.C. (52°46.02′ N, 132°1.02′ W), 8 m, collected by Phil Lambert, 18 Aug 1976.

Pteraster tesselatus Ives, 1888
[Family Pterasteridae]
New depth range: 6 to 436 m.
Previous range: 9 (Lambert 1981) to 436 m (Fisher 1911).
Material: RBCM 973-7-16 (1), Barkley Sound, B.C. (48°52.05′ N, 125°9.12′ W), 6 m, collected by Phil Lambert, 20 Feb 1973. One other lot shallower than 9 m: RBCM 974-223-37 (2), 8 m.

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Literature Cited

Alton, M. S. 1966. Bathymetric distribution of sea stars (Asteroidea) off the northern Oregon coast. Journal of the Fisheries Research Board of Canada 23: 1673–1714.

Clark, A. M. 1989. An index of names of recent Asteroidea — Part 1: Paxillosida and Notomyotida. Pages 225–347 *in* Echinoderm Studies. Volume 3. *Edited by* M. Jangoux, and J. M. Lawrence. A. A. Balkema, Rotterdam/Brookfield. 383 pages.

Clark, A. M. 1993. An index of names of recent Asteroidea — Part 2: Valvatida. Pages 187–366 *in* Echinoderm Studies. Volume 4. *Edited by* M. Jangoux, and J. M. Lawrence. A. A. Balkema, Rotterdam/ Brookfield. 368 pages.

Clark, A. M. 1996. An index of names of recent Asteroidea — Part 3: Velatida and Spinulosida. Pages 183–250 *in* Echinoderm Studies. Volume 5. *Edited by* M. Jangoux, and J. M. Lawrence. A. A. Balkema, Rotterdam/ Brookfield. 250 pages.

D'Yakonov, A. M. 1950. Sea Stars (Asteroids) of the USSR Seas. Zoological Institute of the Academy of Sciences of the USSR [translated 1968 by Israel Program for Scientific Translations, Jerusalem], USSR / Jerusalem. 183 pages.

Fisher, W. K. 1911. Asteroidea of the North Pacific and adjacent waters. Part 1. Phanerozonia and Spinulosa. Volume 1. Smithsonian Institution, Washington, D.C. 419 pages.

Fisher, W. K. 1928. Asteroidea of the North Pacific and adjacent waters. Part 2. Forcipulata (part). Smithsonian Institution, Washington, D.C. 245 pages.

Fisher, W. K. 1930. Asteroidea of the North Pacific and adjacent waters. Part 3. Forcipulata (concluded). Smithsonian Institution, Washington, D.C. 356 pages.

Foltz, D. W. 1998. Distribution of intertidal *Leptasterias* spp. along the Pacific North American coast: A synthesis of allozymic and mtDNA data. *In* Echinoderms: Proceedings of the Ninth International Echinoderm Conference, San Francisco, California. *Edited by* R. Mooi, and M. Telford. A. A. Balkema, Rotterdam/ Brookfield. 923 pages.

Hopkins, T. S., and **G. F. Crozier.** 1966. Observations on the asteroid echinoderm fauna occurring in the shallow water of Southern California (intertidal to 60 metres). Bulletin of the Southern California Academy of Sciences 65: 129–145.

Lambert, P. 1978a. British Columbia marine faunistic survey report: Asteroids from the Northeast Pacific. Fisheries and Marine Service Technical Report Number 773: 1–23.

Lambert, P. 1978b. New geographic and bathymetric records for some northeast Pacific asteroids (Echinodermata: Asteroidea). Syesis 11: 61–64.

Lambert, P. 1981. The Seastars of British Columbia. British Columbia Provincial Museum Handbook Number 39: 1–153.

Mah, C. 1998. New records, taxonomic notes, and a checklist of Hawaiian starfish. Bishop Museum Occasional Papers Number 55:65–71.

Verrill, A. E. 1914. Harrington Alaska Series, Volume 14: Monograph of the shallow-water starfishes of the North Pacific Coast from the Arctic Ocean to California. Part 1 and Part 2. Smithsonian Institution, New York. 408 pages.

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A Toothed Bird *Hesperornis* sp. (Hesperornithiformes) from the Pierre Shale (Late Cretaceous) of Saskatchewan

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Tokaryk, Tim T. 1998. A toothed bird *Hesperornis* sp. (Hesperornithiformes) from the Pierre Shale (Late Cretaceous) of Saskatchewan. Canadian Field-Naturalist 113(4): 670–672.

The recovery of several hesperornithiform bones, identified as *Hesperornis* sp., is the first record for Saskatchewan and extends the geographical range of this genus of toothed birds. It is also the first vertebrate of any kind to be described from the Pierre Shale of Saskatchewan.

Key Words: *Hesperornis*, Cretaceous, Pierre Shale, Saskatchewan.

Cretaceous marine vertebrates of Saskatchewan are less well studied than their terrestrial counterparts. At the same time that dinosaurs were dominating the terrestrial fauna, waters of the epicontinental Western Interior Seaway covered large parts of Saskatchewan and much of the interior of North America. In Saskatchewan, Late Cretaceous rocks of marine origin are exposed primarily in two widespread areas. In the south, the only described material from the Bearpaw Formation (Campanian — early Maastrichtian) are the mosasaur *Plioplatecarpus primaevus* (Tokaryk 1993; Holmes 1996) and a chelonid (Nicholls et al. 1990). Vertebrates from the Belle Fourche Formation (Cenomanian) are a little better studied; the avian material (Cumbaa and Tokaryk 1993; Tokaryk et al., 1996), and scant remains of the chelonid fauna (Nicholls et al. 1990). A selachian fauna, of Late Cretaceous age, has also been described from the same general region (Case et al. 1990).

In 1991 the L'Arrivee family of Arborfield, Saskatchewan, brought to my attention several vertebrate fossils found in the debris pile of a dug-out behind their farm house. This collection includes vertebrae belonging to the marine reptile family Mosasauridae, cranial and postcranial elements of at least two species of teleosts, and the remains of at least two individuals belonging to the avian genus *Hesperornis*.

Previous descriptive work on the Pierre Shale in Saskatchewan centered on the information provided by the biostratigraphy of foraminifera and included only scant mention of vertebrates (see McNeil and Caldwell 1981).

Age of the deposit

The sediment is a friable, black shale. Samples from this locality, SMNH (Royal Saskatchewan Museum) 63E03-0002, were sent to D. H. McNeil and D. J. McIntyre of the Geological Survey of Canada, Calgary. Their work revealed a rich assemblage of dinoflagellates, as well as some pollen species. Foraminifera were not found. Of the dinoflagellates, the signature species *Chatangiella decorosa*, *C. ditissima*, *Isabelidinium microarmum*, *Laciniadinium biconiculum*, and *L. firmum*, suggest an early Campanian age for the Pierre Shale Formation (D. J. McIntyre, personal communication). Nicholls and Russell (1990) believed that the early Campanian vertebrate fauna from this region of North America was part of the Northern Interior Subprovince which was "characterized by a low

TABLE 1. Measurements of proximal ends of tarsometatarsi and probable first vertebra anterior to synsacrum in *Hesperornis*. Abbreviation: SMNH, Royal Saskatchewan Museum, Paleontology collection; USNM, United States National Museum, Smithsonian Institute (see Marsh 1880). All measurements are in millimetres.

	SMNH P2429.1	SMNH P2429.2	USNM 1200	SMNH P2429.5	USNM 1206
Tarsometatarsus					
proximal antero-posterior diameter	18.5	20.9	21.0		
proximal width	29.9	32.2	34.0		
First vertebra anterior to synsacrum					
length of centrum				23.5	25.5
width of anterior articulation				21.9	25.0
height of anterior articulation				12.8	15.0
width of posterior articulation				21.4	26.0
height of posterior articulation				13.5	17.0

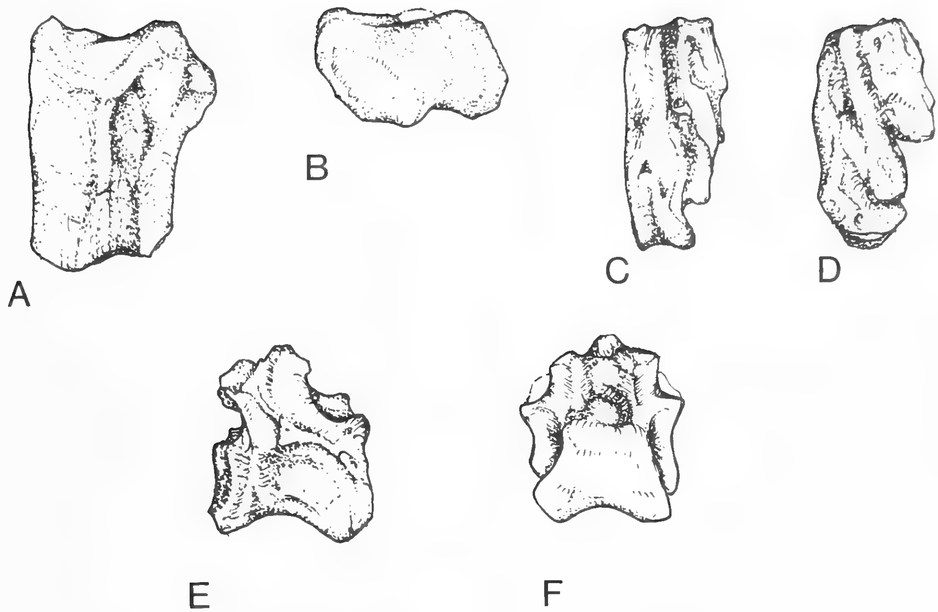

FIGURE 1. *Hesperornis* sp. from the Pierre Shale of Saskatchewan. A and B, SMNH P2429.1, anterior and proximal view of proximal end of tarsometatarsus. C and D, SMNH P2429.6, posterior and medial view of distal end of tarsometatarsus. E and F, SMNH P2429.5, lateral and posterior view of probably the first vertebra anterior to synsacrum. All illustrations × 1.

diversity in all [vertebrate] groups and dominated by plesiosaurs, hesperornithiforms and the mosasaur genus *Platecarpus*" (page 166).

Comparisons were made with specimens *Hesperornis regalis* (see table 1) described and measured by Marsh (1880), *Hesperornis* sp. (Fox 1974), and of *Baptornis* (Martin and Tate 1976). In size and shape, the Saskatchewan specimens are more similar to the larger hesperornithiform *Hesperornis*, than the more diminutive *Baptornis*.

Systematic Paleontology

Class AVES
Order HESPERORNITHIFORMES Furbringer
Family HESPERORNITHIDAE Marsh
Genus *Hesperornis* Marsh
Hesperornis sp.
(Figure 1, Table 1)

Description

Five specimens are referred to the toothed bird *Hesperornis*: SMNH P2429.5 is probably the first vertebra anterior to synsacrum; SMNH P2429.2 and P2429.2 are the proximal ends of right tarsometatarsi; SMNH P2429.6 is the distal end of a right tarsometatarsus; and SMNH P2429.3 is probably the first phalanx from digit four of the right pes.

On the vertebra the postzygapophysis is high above the posterior portion of the centrum while the prezygapophysis is close to the centrum. The articular surfaces of the centrum are saddle-shaped, and deeper posteriorly. Rib articulation is diminutive and the ventral keel on the centrum is not preserved. As compared with cervical hesperornithiform vertebrae, the lack of vertebral complexity, the size, and position of rib articulation suggest that it is a dorsal vertebra, close to the synsacrum.

The proximal articular surfaces of the tarsometatarsi are distinguished by the saddle-shaped internal and external cotyles (the latter is larger than the former) which are separated by a relatively high and distinct intercotylar prominence. A deep, longitudinal inner extensor groove on the anterior surface of the shaft separates them lateral and medially.

On the distal tarsometatarsus the trochlea for digits two, three, and four are preserved. The trochlea for digit two is the largest, is not laterally compressed, and is the most distal in position. More proximal and slightly medial in position is the trochlea for digit three, and even more proximal and ventral but less medial in position is the trochlea for digit four which is similar in latero-medial width to the trochlea for digit three.

Primarily piscivorous, the hesperornithiforms occupied an aquatic habitat rich in food supplies. Although it is best known from the Niobrara Chalk of Kansas, *Hesperornis* has the most extensive geographic range among Cretaceous toothed birds in

North America. In Canada, *Hesperornis* has been recovered from the Pierre Shale of southwestern Manitoba (Bardack 1968; Nicholls 1988), the Foremost Formation of Alberta (Fox 1974), and the Campanian of Northwest Territories (Russell 1967), and the Maastrichtian of Northwest Territories (Rich et. al. 1997). This is the first record of *Hesperornis* from Saskatchewan and is the first vertebrate described from the Pierre Shale of Saskatchewan.

Comments

The avian record from the Cretaceous of Saskatchewan is growing. The shore bird *Cimolopteryx* was described from the Late Maastrichtian (Tokaryk and James 1989); the hesperornithiform *Baptornis* is known from the Campanian (Tokaryk and Harington 1992); and there is a rich avian fauna from the Cenomanian (Tokaryk et al. 1996). One of the factors contributing to this abundance is the fact that, for the most part, Saskatchewan was covered by the Western Interior Seaway for the better part of the Cretaceous. The resulting marine and near-shore paleoenvironments would have been less physically disruptive to the deposition and final preservation of skeletal elements of birds than most terrestrial paleoenvironments.

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Literature Cited

Bardack, D. 1968. Fossil vertebrates from the marine Cretaceous of Manitoba. Canadian Journal of Earth Sciences 5: 145–153.

Case, G. R., T. T. Tokaryk, and **D. Baird.** 1990. Selachians from the Niobrara Formation of the Upper Cretaceous (Coniacian) of Carrot River, Saskatchewan, Canada. Canadian Journal of Earth Sciences 27: 1084–1094.

Cumbaa, S. L., and **T. T. Tokaryk.** 1993. Early birds, crocodile tears and fish tales: Cenomanian and Turonian marine vertebrates from Saskatchewan, Canada. Journal of Vertebrate Paleontology 13(3): 31A–32A.

Fox, R. C. 1974. A middle Campanian, non-marine occurrence of the Cretaceous toothed bird *Hesperornis* Marsh. Canadian Journal of Earth Sciences 11: 1335–1338.

Holmes, R. 1996. *Plioplatecarpus primaevus* (Mosasauridae) from the Bearpaw Formation (Campanian, Upper Cretaceous) of the North American Western Interior Seaway. Journal of Vertebrate Paleontology 16: 673–687.

Marsh, O. C. 1880. Odontornithes. United States Printing Office, Washington, D. C. 201 pages.

Martin, L. D., and **J. Tate, Jr.** 1976. The skeleton of *Baptornis advenus* (Aves: Hesperornithiformes). Pages 35–66 *in* Collected Papers in Avian Paleontology Honoring the 90th Birthday of Alexander Wetmore. *Edited by* S. L. Olson. Smithsonian Contributions to Paleobiology number 27.

McNeil, D. H., and **W. G. E. Caldwell.** 1981. Cretaceous rocks and their foraminifera in the Manitoba escarpment. The Geological Association of Canada, Special Paper number 21.

Nicholls, E. L. 1988. Marine vertebrates of the Pembina Member of the Pierre Shale (Campanian, Upper Cretaceous) of Manitoba and the significance to the biogeography of the western interior seaway. Unpublished doctorate thesis, University of Calgary, Calgary, Alberta.

Nicholls, E. L., and **A. P. Russell.** 1990. Paleobiogeography of the Cretaceous Western Interior Seaway of North America: the vertebrate evidence. Palaeogeography, Palaeoclimatology, Palaeoecology, 79: 149–169.

Nicholls, E. L., T. T. Tokaryk, and **L. V. Hills.** 1990. Cretaceous marine turtles from the Western Interior Seaway of Canada. Canadian Journal of Earth Sciences, 27: 1288–1298.

Rich, T. H., R. A. Gangloff, and **W. R. Hammer.** 1997. Polar Dinosaurs. Pages 562–573 *in* Encyclopedia of Dinosaurs. *Edited by* P. H. Currie and K. Padian. Academic Press.

Russell, D. A. 1967. Cretaceous vertebrates from the Anderson River, N.W.T. Canadian Journal of Earth Sciences 4: 21–38.

Tokaryk, T. T. 1993. A plioplatecarpine mosasaur from the Bearpaw shale (upper Cretaceous) of Saskatchewan, Canada. Modern Geology 18: 503–508.

Tokaryk, T. T., S. L. Cumbaa, and **J. E. Storer.** 1997. Early late Cretaceous birds from Saskatchewan, Canada: the oldest diverse avifauna known from North America. Journal of Vertebrate Paleontology 17: 172–176.

Tokaryk, T. T., and **C. R. Harington.** 1992. *Baptornis* sp. (Aves: Hesperornithiformes) from the Judith River Formation (Campanian) of Saskatchewan, Canada. Journal of Paleontology 66: 1010–1012.

Tokaryk, T. T., and **P. C. James.** 1989. *Cimolopteryx* sp. (Aves, Charadriiformes) from the Frenchman Formation (Maastrichtian), Saskatchewan. Canadian Journal of Earth Sciences 26: 2729–2730.

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Killing of a Muskox, *Ovibos moschatus*, by Two Wolves, *Canis lupus*, and Subsequent Caching

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The killing of a cow Muskox (*Ovibos moschatus*) by two Wolves (*Canis lupus*) in 5 minutes during summer on Ellesmere Island is described. After two of the four feedings observed, one Wolf cached a leg and regurgitated food as far as 2.3 km away and probably farther. The implications of this behavior for deriving food-consumption estimates are discussed.

Key Words: Wolf, *Canis lupus*, Muskox, *Ovibos moschatus*, predation, caching, food consumption, feeding, Northwest Territories, Canada.

"Encounters between wolves and muskoxen are rarely observed and seldom described in detail" (Gray 1987: 127–128). The only complete description of Wolves (*Canis lupus*) killing an adult Muskox (*Ovibos moschatus*) involved a single Wolf (Gray 1970, 1987); in addition, there are two partial accounts of two Wolves killing an adult (Gray 1983), and descriptions of several Wolves killing calves (Mech 1988). Here we describe two Wolves killing an adult, and we provide new information about caching of the kill remains.

The kill we observed took place on Ellesmere Island, Northwest Territories, Canada (80° N, 86°W) on 8 July 1998 when there is continuous daylight. The terrain is barren soil, gravel, rock outcrops and open tundra with no vegetation except widely scattered ground cover. The two Wolves involved were an adult male of unknown origin and a six-year-old female ("Explorer"), which the senior author had habituated to his close presence as a pup around a den in 1992 and studied in 1993 and 1994 (Mech 1995). In 1998, this animal lacked pups, as evidenced by her inconspicuous nipples and nomadic travels.

During the present observations, we used 4-wheeled All Terrain Vehicles to accompany this pair as they traveled and hunted (Mech 1994). We allowed the male to lead, and we paralleled him at distances of 50–100 m, while Explorer remained within a few metres of us; we continually watched ahead for any prey.

At about 0200 on 8 July 1998, the Wolves headed up some foothills along the side of a high escarpment and passed through a valley alongside the ridge. We spotted three Muskoxen about 500 m ahead in a valley at 0224 and immediately stopped and watched through 15X stabilized binoculars. The Wolves continued on toward the Muskoxen, and when about 100 m away, ran straight at them. The Muskoxen fled some 30 m and headed in a tight group up a steep slope, with the two largest animals (one a bull and the other presumably a bull) about half a body length ahead of the smallest, a cow.

As the Muskoxen were running about a third of the way up the slope at 0226, the male Wolf grabbed the last one (a cow) by the rump and hung on, and the female lunged toward the head. The cow wheeled around, and the male lost his grip. Both Wolves focused their attacks on the head and neck of the Muskox, biting at her nose and neck, sometimes hanging on and sometimes losing grip. The Muskox kept pushing up with her lowered head and horns but did not use her hooves. After about 30 seconds of the focused attack, one Wolf gained a solid grip on the cow's nose and the other immediately attacked the side of her neck, repeatedly grabbing a new purchase. The cow appeared to struggle little once the wolves had gained solid grips on her.

The two bulls had stopped about 15 m farther up the hill, and one of them suddenly charged down at the Wolves that were attacking the cow, sending one of the Wolves tumbling about 10 m down the hill. (We could not see whether contact was made, for the bull charged on the opposite side of the cow from us.) The bull hooked repeatedly at the remaining Wolf which eventually released its grip on the cow's nose. By now, the third Muskox had joined the other two, and they headed back up the hill with the cow tightly wedged between the 2 bulls. The Wolves quickly dashed back after the Muskox. Again one of the Wolves grabbed the rump of the cow, which wheeled to meet the wolf head on. The female then grabbed the cow by the nose, and the male by the side of the neck. The wolves kept their grips on the cow for about 30 seconds, and at 0231 the cow fell on a flat area of the hillside about 2/3 toward the top and stopped struggling. The Wolves continued to tear at her head and neck, but the Muskox did not move.

Explorer fed on the Muskox, but the male climbed to the top of the ridge, possibly still wary of us even though we remained about 0.5 km away, and at 0243 he lay down about 20 m above the carcass. Explorer fed on the kill until 0324. She then immediately headed downhill intently searching around as if to begin caching, and went out of sight. At 0340, she passed by us, and we began accompanying her. At 0345, when about 1.5 km from the kill, Explorer dug a hole, regurgitated into it, and covered it. About 50 m away she repeated the behavior. She continued on out of sight at 0349, but the terrain prevented us from following.

At 0413, we saw Explorer about 0.8 km beyond the two caches, returning toward the kill, which she reached at 0441. She then slept near the carcass. Thus she was gone from the carcass for 77 minutes and had traveled at least as far as 2.3 km away from the carcass. From where and when we saw her disappear and reappear, we estimated that she had probably traveled as far as 5 km from the carcass, presumably continuing to cache throughout her trip.

We dug up the two caches and found that their contents of well-chewed, walnut-sized chunks of muscle meat weighed 0.65 and 0.66 kg. A Wolf's stomach can hold 10 kg of meat (Mech unpublished), so if Explorer ate and cached maximally, she could have made about 16 caches of the size we found. Her time and behavior away from the carcass suggests that she did make many caches, but her sleeping and lack of feeding immediately after returning to the carcass suggests that she may have retained at least some of what she had eaten.

We did not observe the Wolves from 0605 to 2150 on 8 July. From 2325 on 8 July to 0003 on 9 July, Explorer again fed on the carcass. Afterwards she alternately slept near the carcass and chased off an Arctic Fox (*Alopex lagopus*).

From 0251 to 0336, 9 July 1998, Explorer fed once more from the carcass. She then pulled off a front leg and shoulder and carried it off while zigzagging and looking around as if searching for a place to cache it. She brought the leg to us, and paraded around us a bit. Her abdomen was noticeably distended. After a couple of minutes, she continued on another 600 m to a rocky stream wash and buried the leg in gravel at 0415; only the hoof and ankle were exposed. She continued on in the same direction as when on her previous caching trip, and we lost sight of her again. We did not see her until she arrived back at the carcass at 0541. Her sides were no longer bulging, so apparently she had continued to cache. When we returned to our lookout at 0445, the male was feeding and he continued to do so until 0537, alternately chasing the Fox. Explorer fed again from 0543 to 0559 and lay down about 30 m away from the carcass. We left at 0645.

When we returned at 2130, the Wolves were gone. We then determined that the Muskox was a cow with well-worn teeth and an estimated 25% fat in her femur marrow. This poor condition may explain why the Wolves so readily attacked the cow and killed her so quickly, for often Wolf attacks on Muskoxen are far more prolonged (Gray 1970, 1983, 1987; Mech 1988 and unpublished). We each independently estimated that the amount eaten and cached from the carcass was about 90 kg, which was about all the readily available flesh.

Most Wolf food consumption estimates (summarized by Mech 1970 and by Schmidt and Mech 1997) are made by calculating the weight of edible material taken from a carcass and dividing that by the number of Wolves and days. In this case, the estimate would have been about 22.5 kg/Wolf/day. However, after two of the four feedings we observed, the Wolf cached unknown amounts. If the amount cached were about equal to that digested, then the actual consumption rate would have been only about half the estimate.

How often Wolves cache after killing large animals is unknown, but such caching is not uncommon (Murie 1944, Cowan 1947, Mech 1988, Mech et al. 1998). However, because most observations of Wolf predation are made from aircraft circling around a kill site for short periods, detailed observations such as we relate here are not usually made. Therefore, we suggest that previous food consumption estimates derived as described above may have to be qualified to account for possible caching that went undetected. In particular, conclusions derived from observations over intervals of a few days could be greatly inflated. We also suggest that future research emphasize attempting to determine how commonly Wolves cache after killing large animals, and under what circumstances.

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Literature Cited

Cowan, I. M. 1947. The timber wolf in the Rocky Mountain national parks of Canada. Canadian Journal Research 25: 139–174.

Gray, D. R. 1970. The killing of a bull muskox by a single wolf. Arctic 23: 197–199.

Gray, D. R. 1983. Interactions between wolves and Muskoxen on Bathurst Island, Northwest Territories, Canada. Acta Zoologica Fennica 174: 255–257.

Gray, D. R. 1987. The Muskoxen of Polar Bear Pass. National Museum of Natural Sciences, National

Museums of Canada. Fitzhenry and Whiteside, Markham, Ontario. 191 pages.
Mech, L. D. 1970. The Wolf: The ecology and behavior of an endangered species. Doubleday Publishing Company, New York. 384 pages.
Mech, L. D. 1988. The arctic wolf: Living with the pack. Voyageur Press, Stillwater, Minnesota. 128 pages.
Mech, L. D. 1994. Regular and homeward travel speeds of arctic wolves. Journal of Mammalogy 75: 741–742.
Mech, L. D. 1995. A ten-year history of the demography and productivity of an arctic wolf pack. Arctic 48: 329–332.
Mech, L. D., L. G. Adams, T. J. Meier, J. W. Burch, and **B. W. Dale.** 1998. The wolves of Denali. University of Minnesota Press, Minneapolis, Minnesota. 227 pages.
Murie, A. 1944. The wolves of Mount McKinley. U.S. National Park Service Fauna Series Number 5. U.S. Government Printing Office, Washington, D. C. 238 pages
Schmidt, P. A., and **L. D. Mech.** 1997. Wolf pack size and food acquisition. American Naturalist 150: 513–517.

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Evaluation of Various Methods Used to Color Mark Ducklings

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Seven methods used to color mark ducklings for the purpose of individual identification were evaluated for retention on groups of domestic ducklings. Marker loss varied considerably among methods and only nasal discs gave satisfactory retention beyond five days. This method of marking ducklings is tentatively recommended for studies concentrating on duckling movement and behavior. Furthermore, it is recommended that before any technique is used, the rate of marker loss be considered in light of the potential to influence results.

Key Words: marker, marking, duckling, nape tag, patagial tag, nasal disc.

Color-marking newly hatched ducklings to monitor subsequent movement, behavior and survival has proven to be problematic. Marking ducklings by injecting vegetable dyes into the egg (Evans 1951) provided a practical method of distinguishing broods during the early stages of development. However, in addition to an increase in embryo mortality due to the treatment (Evans 1951; McAloney 1973), retention time of these dyes was limited as ducklings underwent down loss and feather growth (Guignion 1967). Also, dark coloration of ducklings of many species masks the dyes (McAloney 1973; Milne 1963), further limiting applicability of this technique. Hardware markers such as patagial streamers (Weeks 1972) and nape tags (Bedard and Munro 1977; Foley 1956; McAloney 1973) have been used on ducklings in field situations but we are aware of no study which determined the retention times of these devices in controlled situations before field use on ducklings. Due to their thin and growing skin, ducklings may be more prone to marker loss than are adults of the same species, marked with the same technique. Knowledge of rates of marker loss and length of retention are critical if mortality and survival estimates are objectives of a study.

Once hatched, individual, wild ducklings are difficult to find due to their high mobility, gregarious nature and propensity to seek cover. Relatively few studies have attempted to mark individual ducklings due to difficulties capturing them and in devising a practical means of identification that would not hamper their activities or disrupt brood integrity. During a study of creching behavior of White-winged Scoters (*Melanitta fusca deglandi*) (Kehoe 1986), distinctive marking of individual and brood specific ducklings was necessary. In that study, a marker that would last from hatching to fledging was desired. Several marking systems were tested and evaluated using domestic ducklings (*Anas platyrhynchos*), before attempting to mark young scoters in the field.

Methods

Seven types of markers were tested for retention times, and effects on duckling survival using groups of domestic ducklings in a controlled environment. This environment was considered to give a "best case scenario" with respect to conditions that may influence marker loss. The ducklings were two days old when markers were applied. The marked ducklings were divided into groups of five, based on marker type, and groups were isolated from one another. An unmarked group acted as a control for survival. The groups of ducklings were housed indoors in 2 m diameter pens, on concrete floors and given commercial duck food and water ad libitum for five days. Each pen was heated with a 1000-W infrared light bulb. After five days, ducklings were placed together in an outdoor pen with natural vegetation and a pond. Natural food was supplemented with commercial duck food.

Ducklings from group 1 were marked with a plastic nape tag (Bedard and Munro 1977). This tag consisted of a 2 cm × 3 cm piece of vinyl fabric attached to the duckling with a stainless steel wire bent like a safety pin. Ducklings from group 2 were marked with two colored plastic nasal pieces (Lokemoen and Sharp 1985). Nasal pieces were attached by inserting a stainless steel pin 1.6 mm in diameter through the markers and nares. Stainless steel washers were placed on each end of the marker and both ends of the pin were flattened using a crimp tool and crimped ends were filed smooth. Discs were also crimped apart a fixed distance (12 mm) to allow for bill growth. Ducklings from group 3 were marked with a colored plastic disc sewn to the nape of the neck with a 6-lb test monofilament line. A double stitch suture through the skin attached the disc to the nape. Ducklings from group 4 were marked with a nape streamer (Foley 1956) sutured to the skin as per nape discs of group 3. Streamers were made of a light, flexible, colored plastic approximately 1 cm × 3 cm. Ducklings from group 5 were marked with patagial streamers (Weeks 1972) sewn on with 6 lb test monofilament line. The suture was passed through the patagial web and around the patagial tendon. Sutures were left loose to allow for wing growth. Streamer material was the same as that used for nape streamers. Ducklings from group 6 were marked with a plastic disc the same as those used for groups 2 and 3. The disc was attached to the patagium using the same technique described for group 5. Ducklings from group 7 were marked with a combination patagial disc and streamer that attached with a stainless steel pin and washers; discs were the same as nasal discs in earlier groups and the streamer was the same as in group 5. Monofilament knots for groups 3, 4, 5 and 6 were reinforced with Krazy glue®.

Results and Discussion

After only five days, under controlled conditions, one or more ducklings in all groups except group 1 (nape tag) and group 2 (nasal disc) had lost markers (Table 1). Patagial markers (groups 5, 6, and 7), nape discs (group 3), and streamers (group 4) were therefore judged as unsuitable field markers. Due to logistical constraints, once turned outdoors, ducklings were not monitored to determine when subsequent marker loss occurred. All ducklings survived to 8 weeks when the experiment was terminated (Table 1). However, after 8 weeks the only group in which all ducklings retained their markers was that with nasal discs (Table 1). Only two nape tags were retained and all other markers were lost.

Our results reaffirm the difficulty of marking young ducklings. We postulate that the thin skin of ducklings would not hold most markers tested. Although the nape tags (Group 1) were retained in a controlled environment, most (3 of 5) were lost after the ducklings were placed in an outdoor pen (Table 1). Marker loss in the outdoor pen may have been due either to contact with vegetation or duckling growth. Foley (1956) reported that 70% of Mallard ducklings (*Anas platyrhynchos*) retained nape tags until flying age (about eight weeks). McAloney (1973) reported a 5% loss of nape tags by Eider ducklings, in the first few days post- marking, before they left their nesting island.

Only modified nasal discs gave satisfactory retention beyond 5 days. This method was later used on a small sample of White-winged Scoter ducklings in the field (Kehoe, unpublished data). Before applying nasal discs to wild scoter ducklings, the appropriate distance to crimp the discs apart was determined from bill measurements taken from museum specimens of adult Scoters. Marking wild ducklings with this technique required that the broods be captured in a manner that did not compromise brood integrity. Scoter broods and hens were captured using nest traps which were set when the first eggs were pipping.

TABLE 1. Retention of various markers placed on two-day old domestic ducklings to 5 days and 8 weeks.

	Number of Ducklings with Markers			
Type of Marker	Two-day old	5-day old	8 week old	Number alive at 8 weeks
Nape Tag	5	5	2	5
Nasal Disc	5	5	5	5
Nape Disc	5	3	0	5
Nape Streamer	5	1	0	5
Patagial Streamer	5	0	0	5
Patagial Disc	5	1	0	5
Patagial Disc/Streamer	5	1	0	5

The use of nasal markers on adult waterfowl has become an important tool in waterfowl research (Bartonek and Dane 1964; Greenwood 1977; Greenwood and Sargeant 1973; Lokemoen and Sharp 1985). Although nasal discs did not adversely effect survival of domestic ducklings in controlled situations, further tests must be made to determine if these devices affect behavior and survival of wild ducklings under natural conditions. The extent to which this method affects a duckling's ability to feed in the wild is unknown. Investigators have shown initial, albeit subtle, effects on behavior of adult waterfowl so marked (Byers and Montgomery 1981; Greenwood and Sargeant 1973). Erskine (1972) found nasal discs to adversely affect the survival of Common Mergansers (*Mergus merganser*) in Nova Scotia and New Brunswick.

The potential for physical affects on ducklings resulting from the presence of a marker should be considered in future research; such effects may vary with species and location. Bedard and Munro (1977) found increased predation of Eider ducklings, marked with nape tags (of a design similar to those used on our Group 1) in the St. Lawrence estuary. McAloney (1973) found no difference in predation or survival between nape tag marked and unmarked Eider ducklings in Nova Scotia.

Based on the results of our study we tentatively recommend nasal discs for studies that are concentrating on duckling movement and behavior. However, the application of this technique in the field requires that ducklings be caught immediately after hatching in a manner that does not compromise brood integrity. Furthermore, we caution that before any technique is used, the rate of marker loss should be considered in the light of the potential to influence results. The rates of loss of all markers in our study, except the nasal discs, probably preclude their use in studies of survival. Tests using larger samples of ducklings of various species under controlled settings would give more confidence in our documented rates of marker loss and help determine the best method to apply in field studies.

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Literature Cited

Bartonek, J. D., and **C. E. Dane.** 1964. Numbered nasal discs for waterfowl. Journal of Wildlife Management 28: 688–692.

Bedard, J., and **J. Munro.** 1977. Brood and creche stability in the Common Eider of the St. Lawrence Estuary. Behaviour 60: 221–235.

Byers, S. M., and **R. A. Montgomery.** 1981. Stress response of captive mallards to nasal saddles. Journal of Wildlife Management 45: 498–501.

Evans, C. D. 1951. A method of color marking young waterfowl. Journal of Wildlife Management 15: 101–103.

Erskine, A. J. 1972. Populations, movements and seasonal distribution of mergansers in northern Cape Breton Island. Canadian Wildlife Service Report Series 17. 36 pages.

Foley, D. P. 1956. Use of colored markers on ducklings, New York Fish and Game Journal 3: 241–247.

Greenwood, R. J. 1977. Evaluation of a nasal marker for ducks. Journal of Wildlife Management 41: 582–585.

Greenwood, R. J., and **A. B. Sargeant.** 1973 Influence of radio packs on captive mallards and blue–winged teal. Journal of Wildlife Management 37: 3–9.

Guigion, D. L. 1967. A nesting study of the Common Eider (*Somateria mollissima dresseri*) in the St. Lawrence Estuary. M.Sc. thesis. Laval University, Quebec.

Kehoe, F. P. 1986. The adaptive significance of creching behaviour of the White-winged Scoter (*Melanitta fusca deglandi*). M.Sc. thesis. University of Guelph, Guelph, Ontario.

Lokemoen, J. T., and **D. E. Sharp.** 1985. Assessment of nasal marker materials and designs used on dabbling ducks. Wildllife Society Bulletin 13: 53–56.

McAloney, K. 1973. Brood ecology of the Common Eider (*Somateria mollissima dresseri*) in the Liscombe area of Nova Scotia. M.Sc. thesis. Acadia University, Wolfville, Nova Scotia.

Milne, H. 1963. Seasonal distribution and breeding biology of the Eider (*Somateria mollissima mollisima*) in the northeast of Scotland. Ph.D. thesis. Aberdeen University, Aberdeenshire, Scotland.

Weeks, J. 1972. An improved patagial streamer for waterfowl. Bird Banding 43: 140–141.

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Fall and Winter Diet of Martens, *Martes americana*, in Central Labrador Related to Small Mammal Densities

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Central Labrador trappers returned 252 Marten carcasses from the 1995 through 1997 trapping seasons. Small mammals, mostly *Clethrionomys gapperi*, were the most frequently occurring food category followed by fish (likely trapper's bait), and medium mammals, mostly *Lepus americana*. Frequency of food did not differ between sexes but was different among years. The 1996-1997 diet had a lower proportion of small mammals, and higher proportions of birds and berries than those proportions in the other two seasons. The reduced occurrence of small mammals in the 1996-1997 diet coincided with a reduction in small mammal numbers in Labrador. The reduced adult female per juvenile ratio in 1996-1997 season and reduced Marten harvest in 1997-1998 indicates a food shortage and reduced recruitment.

Key Words: American Marten, *Martes americana*, food habits, small mammals, Labrador.

Trappers in Labrador suggest that American Marten (*Martes americana*) numbers are regulated by small mammal densities. The Boreal Red-backed Vole (*Clethrionomys gapperi*) has been cited as the principal prey species for American Marten (Martin 1994). Other species, Ruffed Grouse (*Bonasa umbellus*), Spruce Grouse (*Dendragapus canadensis*), Red Squirrels (*Tamiasciurus hudsonicus*) and Snowshoe Hares (*Lepus americanus*), are also consumed (Bateman 1986; Thompson and Colgan 1987; Nagorsen et al. 1991; Dempsey and Cumberland 1993*; Poole and Graf 1996). Despite the dietary dominance of arvicoline rodents, Marten recruitment may depend on Snowshoe Hare abundance (Thompson and Colgan 1987; Dempsey and Cumberland 1993; Poole and Graf 1996). Those studies suggest that Martens feed on small mammals opportunistically while selecting Snowshoe Hare for their high caloric value. Whether arvicoline mammals or Snowshoe Hares regulate Marten numbers, the decline of the regulating prey should reduce Marten numbers and recruitment (Thompson and Coglan 1987). This study assesses Marten fall/winter food habits and juvenile to adult female ratios, relating them to relative small mammal abundance.

Study Area and Methods

Marten trappers from Happy Valley-Goose Bay (53°18′ N, 60°20′ W) and Northwest River (53°32′ N, 60°09′ W) submitted 252 Marten carcasses for analysis from October 1995 to March 1998. The year trapped was recorded for 236. We recorded sex, length, weight, tail length, and right hind foot length for all specimens. Age, juvenile or adult ≥ 1.5 years, was determined by the ratio of canine to canine pulp cavity width (Dix and Strickland 1986).

Stomach contents were washed in a 18-grade sieve. Mammals were identified on the basis of teeth, bones, or hair (Day 1966; Adorjan and Kolenosky 1969; Banfield 1987; Thompson et al. 1987). Birds were identified by feet and feathers (Day 1966). Fish were identified by scales and bones and insects by wings and exoskeletons. More detailed taxonomic discriminations within the fish and insect categories were not attempted. Pieces of cut meat were recorded as bait. Food items were expressed in three ways.

Food was grouped into seven categories for analysis (Table 1). A G-test of independence with a Williams correction (G_{adj}) evaluated differences in the frequency of food types between sexes and years and annual differences in adult female per juvenile ratios (Sokal and Rolf 1995).

Results

The most frequent food category encountered was small mammals, mostly *C. gapperi*, followed by fish and medium mammals, mostly *L. americanus* (Table 1). The remaining categories included caribou, birds, berries and empty, all of which occurred in similar frequency. Vegetation (other than berries) occurred relatively frequently, but accounted for little volume.

Because the categories of food consumed did not differ between sexes ($G_{adj} = 4.636$, df = 6, $p > 0.5$), we pooled sexes for annual comparisons. Frequency of food categories consumed differed among years ($G_{adj} = 29.0$, df = 12, $p < 0.01$). In 1995–1996, small mammals were the most frequently occurring food

*See Documents Cited section

TABLE 1. Labrador Marten food by category expressed as frequency of occurrence (freq), proportion of guts (p(gut)), proportion of total food items (p(itm)) and proportion of volume (p(vol)).

	1995				1996				1997			
Food[1]	freq	p(gut)	p(itm)	p(vol)	freq	p(gut)	p(itm)	p(vol)	freq	p(gut)	p(itm)	p(vol)
Small Mammals												
Sorex cinereus	-	-	-	-	1.00	0.01	0.01	-	8.00	0.10	0.07	0.05
Peromyscus maniculatus	-	-	-	-	2.00	0.02	0.02	0.03	-	-	-	-
Clethrionomys gapperi	23.00	0.38	0.35	0.40	7.00	0.08	0.06	0.08	20.00	0.24	0.19	0.16
Phenacomys intermedius	1.00	0.02	0.02	0.01	1.00	0.01	0.01	0.01	2.00	0.02	0.02	0.02
Microtus pennsylvanicus	9.00	0.15	0.14	0.21	1.00	0.01	0.01	0.04	4.00	0.05	0.04	0.02
Dicrostonyx hudsonius	-	-	-	-	-	-	-	-	1.00	0.01	0.01	0.02
Other	1.00	0.02	0.02	0.02	2.00	0.02	0.02	0.01	-	-	-	-
Subtotal	34.00	0.56	0.52	0.67	14.00	0.15	0.11	0.18	35.00	0.42	0.32	0.28
Medium Mammals												
Lepus americanus	7.00	0.11	0.11	0.17	7.00	0.08	0.06	0.05	9.00	0.11	0.08	0.17
Tamiasciurus hudsonicus	-	-	-	-	3.00	0.03	0.02	0.08	1.00	0.01	0.01	0.01
Martes americana	4.00	0.07	0.06	0.09	2.00	0.02	0.02	0.04	3.00	0.04	0.03	0.05
Other	-	-	-	-	4.00	0.04	0.03	0.04	1.00	0.01	0.01	0.01
Subtotal	11.00	0.18	0.17	0.26	16.00	0.17	0.13	0.21	14.00	0.17	0.13	0.25
Rangifer tarandus	1.00	0.02	0.02	0.01	7.00	0.08	0.06	0.10	15.00	0.18	0.14	0.26
Birds												
Lagopus spp	-	-	-	-	3.00	0.03	0.02	0.12	2.00	0.02	0.02	-
Bonasa/Dendragapus spp	2.00	0.03	0.03	0.02	9.00	0.10	0.07	0.11	3.00	0.04	0.03	0.03
Other	1.00	0.02	0.02	0.03	5.00	0.05	0.04	0.02	6.00	0.07	0.06	0.03
Subtotal	3.00	0.05	0.05	0.05	17.00	0.18	0.14	0.26	11.00	0.13	0.10	0.06
Fish	5.00	0.08	0.08	0.01	19.00	0.21	0.15	0.15	12.00	0.14	0.11	0.12
Berries												
Vaccinium vitis-idaea	-	-	-	-	1.00	0.01	0.01	0.01	1.00	0.01	0.01	-
Vaccinium angustifolium	-	-	-	-	18.00	0.20	0.15	0.04	5.00	0.06	0.05	0.01
Amelanchier spp	-	-	-	-	2.00	0.02	0.02	-	1.00	0.01	0.01	-
Subtotal	-	-	-	-	21.00	0.23	0.17	0.05	7.00	0.08	0.06	0.01
Empty	13.00	0.21	0.20	-	11.00	0.12	0.09	-	18.00	0.22	0.17	-
Ursus americanus	-	-	-	-	-	-	-	0.03	2.00	0.02	0.02	0.02
Amphibians	-	-	-	-	1.00	0.01	0.01	0.03				
Insects	-	-	-	-	3.00	0.03	0.02	-	1.00	0.01	0.01	-
Vegetation	9.00	0.15	0.14	-	18.00	0.20	0.15	-	8.00	0.10	0.07	-
Bait	2.00	0.03	0.03	0.04	3.00	0.03	0.02	0.01	1.00	0.01	0.01	0.01
Unidentifiable	-	-	-	-	4.00	0.04	0.03	0.01	2.00	0.02	0.02	-

[1]Those food items which are left justified are the categories used in the analyses.

category followed by medium mammals. In 1996–1997, the principal food categories in descending order of frequency were berries, fish, birds, medium mammals and small mammals. In 1997–1998, the descending order of food frequency was small mammals, caribou, medium mammals, fish and birds.

The reported Marten harvests for Labrador were 744 in 1995–1996, 806 in 1996–1997, and 508 in 1997–1998. The 1995–1996 adult female to juvenile ratio of 1:4.5 was higher than those of 1996–1997 (1:1.233) and 1997–1998 (1:1.263) ($G_{adj} = 4.66$, df = 2, $p < 0.1$). There was an apparent decline in relative small mammal abundance from 20/100 trap nights in 1995–1996 to 1.5/100 trap nights in 1996–1997 (P. Trimper, personal communication).

Discussion

Similar to other areas, the diet of central Labrador Marten consists disproportionately of small mammals, Snowshoe Hares, and grouse (Thompson and Colgan 1987; Dempsey and Cumberland 1993; Poole and Graf 1996). The incidence of fish in Marten food was relatively high. Since water bodies are frozen solid for most of the trapping season, the fish consumed by Martens was likely trapper's bait (Nagorsen et al. 1991). Similar to Nagorsen et al. (1991) and Dempsey and Cumberland (1993) and in contrast with Poole and Graf (1996), male and female Marten ate similar food, indicating no resource partitioning.

The low frequency of small mammals in the 1996–1997 diet coincided with low small mammal numbers in Labrador. There was no compensatory increase in the consumption of Snowshoe Hare that year. Food shortages reduce the energy available for reproduction and should reduce breeding activity to conserve energy and enhance recruitment following the restoration of food resources (Robbins 1983). Our adult female to juvenile ratios indicate a decline in the proportion of young present from the winter of 1995–1996 to the winters of 1996–1997 and 1997–1998. These observations could have resulted from insufficient food for young born in spring of 1996 and reduced productivity in spring 1997. Reduced recruitment may explain the decline in Marten harvested in 1997–1998. Fudge and Associates (1988*) also documented a Marten decline following a small mammal decline in Labrador.

Reduced adult female to juvenile ratios and lower numbers of harvested Marten, following a small mammal decline, suggests that small mammals are an important influence on Labrador Marten numbers.

Acknowledgments

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Documents Cited

Dempsey, J., and **R. Cumberland.** 1993. Diet choice of Marten in New Brunswick application to a Marten management model. Furbearer Report # 6. Fish and Wildlife Branch, New Brunswick.

Fudge and Associates Limited. 1988. Implications of a small mammal decline on Marten of the Ungava Peninsula. Prepared for Fenco Lavalin Inc. and The Department of National Defence.

Literature Cited

Adorjan, A. S., and **G. B. Kolenoski.** 1969. A manual for the identification of hairs of selected Ontario mammals. Ontario Ministry of Natural Resources Research Report (Wildlife) 90. 64 pages.

Banfield, A. W. F. 1987. The mammals of Canada. Second Edition. University of Toronto Press, Toronto, Ontario.

Bateman, M. C. 1986. Winter habitat use and home range size of the Marten, *Martes americana*, in western Newoundland. Canadian Field-Naturalist 100: 58–62.

Day, M. G. 1966. Identification of hair and feather remains in the gut and faeces of stoats and weasels. Journal of Zoology 148: 201–217.

Dix, L. M., and **M. A. Strickland.** 1986. Use of radiographs to classify Martens by sex and age. Wildlife Society Bulletin 14: 275–279.

Martin, S. K. 1994. Feeding ecology of American Martens and fishers. Pages 297–315 *in* Martens, sables and fishers: Biology and conservation. *Edited by* S. W. Buskirk, A. S. Harestad, M. G. Raphael and R. A. Powell. Cornell University Press, Ithaca, New York.

Nagorson, D. W., R. W. Campbell, and **G. R. Giannico.** 1991. Winter food habits of Marten, *Martes americana*, on the Queen Charlotte Islands. Canadian Field-Naturalist 105: 55–59.

Poole, K. G., and **R. P. Graf.** 1996. Winter diet of Marten during a snowshoe hare decline. Canadian Journal of Zoology 74: 456–466.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press, Toronto.

Sokal R. R, and **F. J. Rolf.** 1995. Biometry. 3rd edition, Freeman and Company, New York. 887 pages.

Thompson, I. D., and **P. W. Colgan.** 1987. Numerical responses of Marten to food shortage in northcentral Ontario. Journal of Wildlife Management 51: 824–855.

Thompson, I. D., M. S. Porter, and **S. L. Walker.** 1987. A key to the identification of some small boreal mammals of central Canada from guard hairs. Canadian Field-Naturalist 101: 614–616.

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Distribution of the Pygmy Shrew, *Sorex hoyi*, in Montana and Idaho

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Foresman, Kerry R. 1999. Distribution of the Pygmy Shrew, *Sorex hoyi*, in Montana and Idaho. Canadian Field-Naturalist 113(4): 681–683.

One hundred seventeen *Sorex hoyi* specimens reported since 1986 expand the known distribution of the Pygmy Shrew in Montana and Idaho.

Key Words: Pygmy Shrew, *Sorex hoyi*, distribution, Montana, Idaho.

The Pygmy Shrew, *Sorex hoyi,* is considered an uncommon species in the northwestern United States, with only a few specimens documented in Washington (n = 7; Jackson 1925; Stinson and Reichel 1985) and Montana (n = 16; Koford 1938; Setzer 1952; Hoffmann et al. 1969; Key 1979) prior to 1985. I began intensive, long-term studies on the soricids of western Montana, and adjacent areas of Idaho in 1985. Twenty-three sites were selected at elevations ranging from 1100 to 3350 m. Habitat types represented were sagebrush steppe (n = 2), short grass prairie (n = 2), Cottonwood (*Populus deltoides*) riparian zone (n = 2), Western Redcedar (*Thuja plicata*)/Douglas Fir (*Pseudotsuga menziesii*) riparian zone (n = 1), Douglas Fir/Western Larch (*Larix occidentalis*)/Ponderosa Pine (*Pinus ponderosa*) forest (n = 13), Subalpine Fir (*Abies lasiocarpa*)/Grand Fir (*A. grandis*)/Engelmann Spruce (*Picea engelmannii*) forest (n = 2), and alpine (n = 1). Pitfall traps were employed at all sites and monitored for 13 years (> 127 000 trap nights). More than 2540 soricids of seven different species were collected, 116 of which were *Sorex hoyi.* Ten of these specimens were collected between 1985 and 1988 in Idaho County, Idaho, 7 km west of the Montana/Idaho border. The first two of these captures mark the first records of Pygmy Shrews in Idaho (Foresman 1986). One additional specimen was collected in 1987 in Beaverhead County, Montana (van Sickle 1987*) bringing the total number of new specimens to 117 (Table 1, 2; Figure 1).

TABLE 1. Sex/Age class of *Sorex hoyi* collected in Montana and Idaho between 1986 and 1998.

Site[1]	Sex/Age[2]								
	Male			Female			Unknown		
	Juvenile	Adult	Unknown	Juvenile	Adult	Unknown	Juvenile	Adult	Unknown
Patte Canyon	3	0	0	3	0	0	0	1	0
Miller Creek	0	0	1	0	0	0	0	0	0
Swan Valley	19	8	2	15	1	1	25	11	0
Helena	0	4	0	0	0	0	8	0	0
Big Hole Battlefield[3]	1	0	0	0	0	0	0	0	0
Spruce Creek[4]	4	2	1	0	1	0	0	0	0
Total =	27	14	4	18	2	1	33	12	0

[1]Refer to text for specific site locations.
[2]Juvenile = First summer juvenile (0–6 months of age) (Age classes determined by tooth wear analysis as per Rudd 1955).
[3]van Sickle (1987).
[4]Two specimens collected in 1985 were previously described (Foresman 1986).

TABLE 2. Weights of *Sorex hoyi* collected in Montana and Idaho between 1986 and 1998.

	Mean Weight [g] ± S.D. (n)[2]	
Site[1]	Juveniles	Adults
Pattee Canyon	1.93 ± 0.14 (5)	2.26 (1)
Miller Creek	No weight or age determined	
Swan Valley	2.38 ± 0.60 (38)	3.06 ± 0.60 (9)
Helena	2.0 ± 0.00 (2)	3.29 ± 0.42 (6)
Big Hole Battlefield[3]	1.63 (1)	0
Spruce Creek, Idaho[4]	2.05 ± 0.14 (4)	3.18 ± 1.37 (2)
		4.44 (1) Pregnant

[1]Refer to text for specific site locations.
[2]Since no sex differences were noted (with the exception of the pregnant individual), values for ♂'s and ♀'s were combined.
[3]van Sickle (1987).
[4]Two specimens collected in 1985 were previously described (Foresman 1986).

A variety of habitat types and small mammal species associations were represented at the collection localities. Drier sagebrush steppe conditions dominated by Big Sagebrush (*Artemisia tridentata*)/Idaho Fescue (*Festuca idahoensis*) occurred at the Big Hole National Battlefield, Beaverhead County (T2S, R17W, Sect. 24). Here, the Common Shrew (*Sorex cinereus*), Vagrant Shrew (*S. vagrans*), Preble's Shrew (*S. preblei*), Deer Mouse (*Peromyscus maniculatus*), Montane Heather Vole (*Phenocomys intermedius*), Western Jumping Mouse (*Zapus princeps*), and Columbian Ground Squirrel (*Spermophilus columbianus*) were also collected. Douglas Fir/Western Larch/ Ponderosa Pine/Lodgepole Pine overstory with an Arnica (*Arnica cordifolia*), Shiny-leaf Spiraea (*Spiraea betulifolia*), Service Berry (*Amelanchier alnifolia*), Creeping Oregon Grape (*Berbis repins*), Snowberry (*Symphoricarpos occidentalis*) understory characterized five localities in Missoula County — Pattee Canyon (T12N, R18W, Sect. 7), Miller Creek (T11N, R18W, Sect. 7,18), and Swan Valley (3 sites, T22N, R17W, Sect. 5; T21N, R17W, Sect. 14, 23, 24; T19N, R16W, Sect. 6; T20N, R16W, Sect. 31, 32), and one in Lewis and Clark County — Helena (T9N, R5W, Sect. 12). Species associations at these sites included the Common Shrew, Vagrant Shrew, Montane Shrew (*Sorex monticolus*), Deer Mouse, Long-tailed Vole (*Microtus longicaudus*), Meadow Vole (*M. pennsylvanicus*), Red-Backed Vole (*Clethrionomys gapperi*), Yellow Pine Chipmunk (*Tamias amoenus*), Red-tailed Chipmunk (*T. ruficaudus*), Columbian Ground Squirrel, and Bushy-tailed Woodrat (*Neotoma cinerea*). The last locality was dominated by Subalpine Fir, Grand Fir, and Engelmann Spruce with an understory of Mountain Gooseberry (*Ribes* spp.), horsetail (*Equisetum* spp.), and sedges (*Carex* spp.) [Idaho County, Idaho — Spruce Creek (T38N,R16E, Sect. 25)]. Here, the Common Shrew and Vagrant Shrew were also collected as were Red-backed Voles, Montane Voles, and the Northern Pocket Gopher (*Thomomys talpoides*). This habitat diversity supports earlier reports that the Pygmy Shrew is adapted to a wide range of conditions (Long 1972). Many Montana sites are consistent with the habitat characteristics observed in Washington (Douglas Fir, Ponderosa Pine, Lodgepole Pine overstory with a Creeping Oregon Grape, Shiny-leaf Spirea, Snowberry understory; Stinson and Reichel 1985), and the Idaho site is similar to spruce-fir forests in Manitoba (Buckner 1966), Colorado (Spencer and Pettus 1966), and Wyoming (Brown 1966, 1967), although no true sphagnum bog was present. Of the 82 specimens collected in the Swan Valley, 73% (n = 60) were obtained one to three years after timber harvest (Naughton et al. 1999*). Pygmy Shrews may either prefer drier habitats or be forced into these sites through interspecific competition (Foresman and Henderson 1999*).

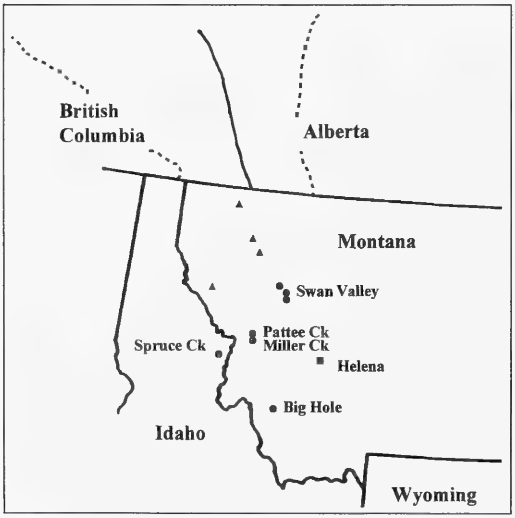

FIGURE 1. Distribution of *Sorex hoyi* in Montana and Idaho. Circles identify new records, triangles designate specimens obtained prior to 1985 [refer to text for specific site locations of new records; earlier records from top to bottom: Key 1979; Koford 1938; Hoffmann et al. 1969; Setzer 1952]. Canadian distribution bordering Montana lies between dotted lines (van Zyll de Jong 1983).

Although this species should be considered uncommon in Montana and possibly in Idaho, its rarity in collections is most likely due to limited efforts using effective trapping methods such as pitfall traps. The results of my study and the occurrence of populations in southeastern Wyoming (Brown 1966, 1967) and northcentral Colorado (Spencer and Pettus 1966), indicate additional populations may exist throughout the Rocky Mountain chain between these localities.

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Documents Cited [marked * in text citations]

Foresman, K. R., and **C. B. Henderson.** 1999. Response of soricid populations to two forest management alternatives. Manuscript in review.

Naughton, G. P., C. B. Henderson, K. R. Foresman, and **R. L. McGraw.** 1999. Long-toed salamanders (*Ambystoma macrodactylum*) in harvested and intact Douglas-fir forests of western Montana. Ecological Applications in press.

van Sickle, W. 1987. Survey of vertebrates on the Big Hole National Battlefield. Wyoming Cooperative Fishery and Wildlife Research Unit. Report 88–01.

Literature Cited

Brown, L. N. 1966. First record of the pigmy shrew in Wyoming and description of a new subspecies (Mammalia: Insectivora). Proceedings of the Biological Society of Washington. 79: 49–51.

Brown, L. N. 1967. Ecological distribution of six species of shrews and comparison of sampling methods in the central Rocky Mountains. Journal of Mammalogy 48: 617–623.

Buckner, C. H. 1966. Populations and ecological relationships of shrews in tamarack bogs of southeastern Manitoba. Journal of Mammalogy 47: 181–194.

Foresman, K. R. 1986. *Sorex hoyi* in Idaho: A new state record. Murrelet 67: 81–82

Hoffmann, R. S., P. L. Wright, and **F. E. Newby.** 1969. The distribution of some mammals in Montana I. Mammals other than bats. Journal of Mammalogy 50: 579–604.

Jackson, H. H. T. 1925. Two new pigmy shrews of the genus *Microsorex*. Proceedings of the Biological Society of Washington 38: 125–126.

Key, C. H. 1979. Mammalian utilization of floodplain habitats along the north fork of the Flathead River in Glacier National Park, Montana. Ph.D. dissertation, University of Montana, Missoula, Montana. 151 pages.

Koford, C. B. 1938. *Microsorex hoyi washingtoni* in Montana. Journal of Mammalogy 19: 372.

Long, C. A. 1972. Notes on habitat preference and reproduction in pigmy shrews, *Microsorex*. Canadian Field-Naturalist 86: 155–160.

Rudd, R. L. 1955. Age, sex, and weight comparisons in three species of shrews. Journal of Mammalogy 36: 323–339.

Setzer, H .W. 1952. Pigmy shrew, *Microsorex*, in Montana. Journal of Mammalogy 33: 398.

Spencer, A. W., and **D. Pettus.** 1966. Habitat preferences of five sympatric species of long-tailed shrews. Ecology 47: 677–683.

Stinson, D. W., and **J. D. Reichel.** 1985. Rediscovery of the pygmy shrew in Washington. The Murrelet 66: 59–60.

van Zyll de Jong, C. G. 1983. Handbook of Canadian mammals: Marsupials and insectivores. National Museum of Canada, Ottawa, Canada. 210 pages.

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Appendix I: Specimens Examined[1]

Missoula County, Montana
- Pattee Canyon - KRF 644, 650, 662, 667, 693, 703, 706, 720
- Miller Creek - KRF 835
- Swan Valley - KRF 1516, 1529, 1530, 1546, 1604, 1605, 1617, 1618, 1620, 1641, 1646, 1667, 1673, 1700, 1722, 1723, 1768, 1828, 1836, 1905, 1925, 1932, 1933, 1956, 1964, 1968, 1970, 1979, 1980, 1981, 1987, 1988, 1996, 2007, 2012, 2018, 2037, 2041, 2056, 2066, 2069, 2072, 2077, 2078, 2084, 2085, 2098, 2109, 2112, 2117, 2129, 2134, 2141, 2143, 2144, 2146-2150, 2152, 2154, 2159, 2160, 2162, 2194-2206, 2281, 2534-2536

Lewis and Clark County, Montana
- Helena - KRF 1478, 1479, 1481, 1491-1497, 2537-2540

Beaverhead County, Montana
- Big Hole Battlefield - KRF 642

Idaho County, Idaho
- Spruce Creek - KRF 751, 780, 786, 791, 802, 809, 814

[1]All specimens are maintained in the author's collection at The University of Montana.

*See Documents Cited section.

Predation on a Meadow Jumping Mouse, *Zapus hudsonius*, and a House Mouse, *Mus musculus*, by Brown Trout, *Salmo trutta*

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Cochran, Philip A., and Joseph A. Cochran. 1999. Predation on a Meadow Jumping Mouse, *Zapus hudsonius*, and a House Mouse, *Mus musculus*, by Brown Trout, *Salmo trutta*. Canadian Field-Naturalist 113(4): 684–685.

A Brown Trout collected in a Wisconsin stream contained the remains of a juvenile Meadow Jumping Mouse. This is the second reported occurrence of predation by a fish on a member of this species, which occurs commonly in riparian habitats. A Brown Trout from a Minnesota stream contained an adult House Mouse.

Key Words: Meadow Jumping Mouse, *Zapus hudsonius*, House Mouse, *Mus musculus*, Brown Trout, *Salmo trutta*, Salmonidae, predation, Wisconsin.

The Meadow Jumping Mouse [*Zapus hudsonius* (Zimmermann)] is found over much of the United States and Canada (Whitaker 1972; Whitaker and Hamilton 1998). Its habitat includes thick vegetation along streams, and it is reported to dive and swim well (Jones and Birney 1988). Whitaker (1963) reviewed known instances of predation on Meadow Jumping Mice and found only one case of predation by a fish (a Northern Pike, *Esox lucius*). However, Jackson (1961) suggested that predatory fishes such as Northern Pike, Muskellunge (*E. masquinongy*), and black bass (*Micropterus* spp.) would readily eat Meadow Jumping Mice if given the opportunity, and Largemouth Bass (*M. salmoides*) have been found to prey upon a related species, the Woodland Jumping Mouse (*Napeozapus insignis*) (Hodgson 1986; Hodgson and Kinsella 1995). We report here a case of fish predation on a Meadow Jumping Mouse in Manitowoc County, Wisconsin. Meadow Jumping Mice were previously reported from Manitowoc County and most adjacent counties by Jackson (1961).

On 19 September 1995, we collected a Brown Trout (*Salmo trutta* L.) by angling in Jambo Creek within 100 m of its confluence with the East Twin River (44°15′ N, 88°40′ W). Water temperature was 10.5° C. The trout, 29 cm in total length, contained a Meadow Jumping Mouse (total length: 16 cm; tail length: 11 cm; hind foot length: 29 mm).

On 20 June 1999, we collected a Brown Trout by angling in Gilmore Creek approximately 100 m upstream from U.S. Highway 14, Winona County, Minnesota (44°02′N, 91°41′W). The trout, 39 cm in total length, contained a House Mouse (total length 14 cm; tail length: 6 cm; hind foot length 21 mm). The section of stream where the trout was captured passes a field habitat bordered on one side by suburban residental development, a likely source of House Mice.

In contrast to the Meadow Jumping Mouse, the House Mouse (*Mus musculus* L.) is an exotic species in North America. Althought it is commonly associated with houses, barns, and other buildings, it may be found in fields and meadows (Jackson 1961). We are unaware of prior reports of predation by fish on this species.

Brown Trout have been previously reported to feed on small mammals (Scott and Crossman 1973; Becker 1983), although the small sizes of the individuals reported here relative to their prey is somewhat surprising. Their inclination to strike a lure with such a large prey item already in their stomachs was also surprising, but Eddy and Underhill (1974) described a similar example.

Brown Trout are not native to North America. They can inhabit somewhat warmer water than the smaller, native Brook Trout (*Salvelinus fontinalis*) and tend to displace the latter in some stream systems (Becker 1983). Widespread stocking of Brown Trout may have had the incidental effect of increasing the level of predation to which species such as the Meadow Jumping Mouse are exposed in systems not formerly inhabited by many large aquatic predators.

The preserved remains of the mice are being held in the St. Norbert College biology discipline's teaching collection.

Acknowledgments

I thank J. R. Hodgson for confirming the identification of the mice and for the use of bibliographic materials.

Literature Cited

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison, Wisconsin. 1052 pages.

Eddy, S., and **J. C. Underhill.** 1974. Northern fishes, 3rd edition. University of Minnesota Press, Minneapolis, Minnesota. 414 pages.

Hodgson, J. R. 1986. The occurrence of mammals in the diets [sic] of largemouth bass (*Micropterus salmoides*). The Jack-Pine Warbler 64: 39–40.

Hodgson, J. R., and **M. J. Kinsella.** 1995. Small mammals in the diet of largemouth bass, revisited. Journal of Freshwater Ecology 10: 433–435.

Jackson, H. H. T. 1961. Mammals of Wisconsin. University of Wisconsin Press, Madison, Wisconsin. 504 pages.

Jones, J. K., Jr., and **E. C. Birney.** 1988. Handbook of Mammals of the North-central States. University of Minnesota Press, Minneapolis, Minnesota. 346 pages.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada Bulletin 184. 966 pages.

Whitaker, J. O., Jr. 1963. A study of the meadow jumping mouse, *Zapus hudsonius* (Zimmerman), in central New York. Ecological Monographs 33: 215–254.

Whitaker, J. O., Jr. 1972. *Zapus hudsonius*. Mammalian Species, Number 11, pages 1–7.

Whitaker, J. O., Jr. , and **W. J. Hamilton, Jr.** 1998. Mammals of the Eastern United States, 3rd edition.Comstock Publishing Associates, Ithaca, New York. 583 pages.

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News and Comment

Notices

Alberta Wildlife Status Reports (18 to 21)

The Fisheries and Wildlife Management Division of the Alberta Natural Resource Status and Assessment Branch, Alberta Environmental Protection, has released Wildlife Status Reports numbers 18 to 22. The Series Editor for these is Isabelle M. G. Michaud (= Richardson in previous reports 13-17), the Senior Editor is David R. C. Prescott, and the illustrations are by Brian Huffman. For a listing earlier numbers in the series, see *The Canadian Field-Naturalist* 112(1): 169 for 1–11 and 113(2): 311 for 12–17.

The newly published reports are:

18. Status of the Ferruginous Hawk (*Buteo regalis*) in Alberta, by Josef K. Schmutz. 18 pages.
19. Status of the Red-tailed Chipmunk (*Tamias ruficaudus*) in Alberta, by Ron Bennett. 15 pages.
20. Status of the Pigmy Owl (*Glaucidium gnoma californicum*) in Alberta, by Kevin C. Hannah. 20 pages.
21. Status of the Western Blue Flag (*Iris missouriensis*) in Alberta, by Joyce Gould. 22 pages.

For copies: Information Centre — Publications, Alberta Environmental Protection, Natural Resources Service, Main Floor, Great West Life Building, 9920 – 108 Street, Edmonton, Alberta T5K 2M4, Canada (telephone: (780) 422-2079), OR Information Service, Alberta Environmental Protection, #100, 3115 - 12 Street NE, Calgary, Alberta T2E 7J2, Canada (telephone: (403) 297-3362); or contact Isabelle M. Michaud, 7th Floor, O. S. Longman Building, 6909 – 116 Street, Edmonton, Alberta T6H 4P2: telephone (780) 427-1248; fax (780) 427-9685; e-mail Isabelle.Michaud@gov.ab.ca

Sea Wind: Bulletin of Ocean Voice International 13(1), 13(2), 13(3)

13(1) January–March 1999 issue, 40 pages, contains: Poem — Spirit of Haida Gwaii; Annual General Meeting and Report of Ocean Voice International; Ocean Voice International Annual Report, March 23rd 1998 to March 14th 1999; Striking a Balance — The Role of Industry and Government in the Current New Brunswick Salmon Aquaculture Crisis; Coral Reef Restoration and Shore Protection Using Mineral Accretion and Renewable Energy; The Halifax Declaration on the Ocean; Quotas For Sustainability; Ode to a Seagull; Sea News; Marine Courses; On The Net; Book Nooke.

13(2) April-June 1999, 36 pages contains: The orange roughy (*Holplostethus atlanticus*), tasty, deep-dwelling and long-lived fish: At risk?; The Magnificent Frigatebird; Marine Aquarium Council Progress; Quotes; Sea News; Marine Courses; On The Net; Book Nooke.

13(3) July-August 1999, 40 pages, contains: Eco-labelling for small-scale fishers and consumers; Mariculture in the Deserts; Green School Coral Booklet Published; Global Trawling Ground Survey Status; Progress on Caribbean Coral Reef Education Project; A Code of Ethics for Anglers; Thanks to Supporters; Sea News; On the Net; Cigua-Check: Ciguatera Fish Poison Test Kit Introduced; Booke Nooke.

Sea Wind is edited by Donald E. Mcallister (e-mail: mcall@superaje.com) and is available though subscription or membership in Ocean Voice International Inc., P. O. Box 37026, 3332 McCarthy Road, Ottawa, Ontario K1V 0W0, Canada; e-mail: ovi@cyberus.ca; World-Wide Web site: <http://www.ovi.ca>.

Marine Turtle Newsletter (85)

Number 85, July 1999, 32 pages, contains: EDITORIAL: MTN/NTM Housekeeping: ARTICLES: Results of the Kemp's Ridley Nesting Beach Conservation Efforts in Mexico; Marine Turtle Survey at Phra Thong Island, South Thailand; Current Status of Nesting Sea Turtles in Northern Columbian Caribbean; Sea Turtles of El Salvador; NOTES: Olive Ridley Turtle Records from South Banyuwangi, East Java; From One Feeding Ground to Another — Green Turtle Migration between Brazil and Nicaragua; MEETING REPORTS; ANNOUNCEMENTS; NEWS & LEGAL BRIEFS, RECENT PUBLICATIONS; PUBLICATION REVIEWS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, UK; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; Fax + 1 978 840 8184. MTN website is: <http://www.seaturtle.org/mtn/>

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF) (33 and 34)

Number 33, June 1999, 4 pages, contains: Philippine Amphibians Assessment (Chris Banks); Report from Panama (Roberto Ibanez); UNEP Ozone Depletion Report; Infectious Disease and Amphibian Population Dynamics: Is Egg Mortality Significant? (Jim Robinson, Richard Griffiths, and Peter Jeffries); United States Working Group Report (Mike Lannoo); Listing Recently Extinct Amphibians (Tim Halliday); Lincoln Park Zoo Grants Available; Tennessee Herpetology Conference; Froglog Shorts; Publications of Interest.

Number 34, August 1999, 4 pages, contains: Report from the DAPTF chair (W. Ronald Heyer), New Seed Grant Round (International Conservation Awards; Unrestricted Awards; Working Group "Harvest Grants" (T. R. Halliday), Amphibian Decline Monitoring in the Leuser Management Unit, Aceh, North Sumatra, Indonesia (Dojoko T. Iskandar; Expansion of *Rana ridibunda* in the Urals — A Danger for Native Amphibians? (Vladimir Vershinin & Irina Kamkina), Advances in the Conservation Status of Uruguayan Amphibians (Raul Maneyro & Jose A. Langone), Request for Information from Working Groups (John Wilkinson); Froglog Shorts, Publications of Interest.

Froglog is sponsored by The World Conservation Union (IUCN)/Species Survival Commission (SSC); The Open University; The World Congress of Herpetology; and The Smithsonian Institution; and is available by contacting Editor John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk

Recovery: An Endangered Species Newsletter (13)

The June 1999 issue, 8 pages, contains: First recovery plan for a tree underway [Red Mulberry, *Morus rubra*] (John Ambrose); Commentary: Species protection in balance (Kim Pollock, Director of Environment and Public Policy for the Industrial Wood and Allied Workers of Canada); Message from the Minister: Working together on species at risk (The Honourable Christine Stewart, Minister of the Environment, Canada); ESRF [Endangered Species Recovery Fund] Update: A natural legacy for a new era — Conservation groups look to the next millennium (Cathy Merriman); CITES Update — CITES meeting April 2000 [Nairobi, Kenya]; RENEW Update; Essay — The Australian approach: Words of wisdom from abroad (Simon Nadeau); Recovery Watch: All in the details — Saving wildlife comes under the microscope (Christie Spence and Kent Prior), Invasive Aliens — Endangered species millennium bug? (Kent Prior); Recovery Watch: A species on the brink — The right genetic data could save the right whale (Brad White); Featured Species: The view from above — Satellites shed new light on Harlequin Ducks (Jean-Pierre L. Savard and Serge Bodeur), Identifying distinct populations (Kathy Dickson).

Recovery is available from the Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada or is accessible on the net at: http://www.cws-scf.ec.gc.ca/es/recovery/archive.html

The Boreal Dip Net Newsletter of the Canadian Amphibian and Reptile Conservation Network 3(1&2)

The Winter-Fall 1998 issue contains: From the Editor; News from COSEWIC; Website Update; News from Eastern Canada (Carolyn Seburn); Les Novelles de Quebec (Jacques Jutras); A Report on the 78th Annual Meeting of the Society for Northwestern Vertebrate Biology (in association with PNARC [Pacific Northwest Amphibian and Reptile Consortium) (Larry Powell); Le Code de Deontologie du DAPTF pour la Researche sur le Terrain — A New Code of Practice For Field Studies on Amphibians from the DAPTF [Decline in Amphibian Populations Task Force] (Martin Ouellet); Possible Ways to Incorporate the DAPTF Fieldwork Code of Practice into Field Work (Danna Schock); Saskatoon Hosts a Great Meeting; Grasslands National Park, Saskatchewan: Field Report; Abstracts From the Saskatchewan Conference [24]; Fungal Disease Confirmed as Serious Threat to Western Australia's Frogs; Donations to CARCN ... (Wayne Weller); Success from Our First Public Appeal; Help make Canada More Herp-friendly; Museums, Biodiversity and Science.

For membership or additional information contact Stan Orchard, Editor, the Boreal Dipnet, Canadian Amphibian and Reptile Conservation Network/Reseau Canadien de Conservation des Amphibiens et des Reptiles, 1745 Bank Street, Victoria, British Columbia V8R 4V7, Canada, or visit their web site at http://cciw.ca/ecowatch/dapcan.

Canadian Association of Herpetologists *Bulletin* 13(1)

The Spring 1999 issue is 24 pages and contains MEETINGS: Conservation and Ecology of Sea Turtles of the Mid-Atlantic Region, October 30–31 (Chris Swarth): Canadian Amphibian and Reptile Conservation Network Annual Meeting, October 15–18, in Quebec City; FEATURE SECTION Paleontology and Herpetology: The Ancestry and Interrelationships of Modern Amphibians (Robert L. Carroll); Recent Work on Early Stegocephalian Evolution

(Michel Laurin), Current Research on Albanerpetonid Amphibians — A North American Perspective (James D. Gardner); ARTICLES: Some Good News for a Change? ... Amphibians are Doing Fine in the Logged Hardwood Forests of Algonquin Park, Ontario! (Lisa Enright); Island of the Snake — Herpetology in Guam (David Cunnington); COSEWIC 1999 — New Species Added to the Canadian At-Risk List (David M. Green); BOOK REVIEWS (Patrick T. Gregory; David Green); PUBLICATIONS OF INTEREST (Jon Davidson); THESIS ABSTRACTS IN CANADIAN HERPETOLOGY: Effects of Selective Logging on Amphibian Diversity and Abundance in Shade-tolerant Hardwood Forests of Algonquin Park, Ontario (Lisa Enright, MSc 1998, University of Guelph, Supervisor R. J. Brooks); Structure and Evolution of Supernumerary Chromosomes in the Pacific Giant Salamander, *Dicamptodon tenebrosus* (Jacqueline Brinkman, MSc., Redpath Museum, McGill University, Supervisor D. M. Green).

The *Bulletin* is edited by Shane De Solla, Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1; e-mail ssolla@uoguelph.ca; the Production Editor is David M. Green, Redpath Museum, McGill University, 859 Sherbrooke Street West, Montreal, Quebec H3A 2K6. Membership in the Canadian Association of Herpetologists/ Association Canadienne des Herpetologistes is $10.00 for regular members and $5.00 for students. Contact Dr. Patrick T. Gregory, Treasurer CAH/ACH, Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2, Canada.

The Aquatic and Wetland Plant Information Retrieval System (APIRS)

This free information service has been collecting research articles relating to aquatic and wetland plants for more than 15 years. At present, the database contains over 48 000 citations about aquatic and wetland plant ecology, physiology, morphology, utilization and more. It is also collecting literature on upland invasive species in Florida. Citations, keywords, and plant names form the literature are entered into a computerized data base form which bibliographies, corresponding to any combination of user-specified terms. Database searches can be performed by program staff or may be performed by users online via Internet World Wide Web site. Hard copies of most references are on file and available for reference use. Any researcher, student, water resource manager, or government agency employee is eligible to use this system. Users are requested to send regularly their own reprints to be entered into the APIRS collection. Contact Centre for Aquatic and Invasive Plants, Institute of Food and Agricultural Sciences, University of Florida, 7922 N.W. 71st Street, Gainesville, Florida 32653 USA; Telephone (352) 392-1799; Fax (352) 392-3462; e-mail varamey@nervm.nerdc.ufl.edu; URL http://aquatl.ifas.ufl.edu/

Nova Scotia Herpetofaunal Atlas pamphlet and on the web

A full-colour pamphlet funded by the Federation of Nova Scotia Naturalists gives field identification, habitat and status for amphibians and reptiles in Nova Scotia. It features colour photographs by Ron Merick and watercolours by Fred Scott illustrating every frog (8), salamander (5), snake (5), and turtle (4) species that has been recorded in the province. Habitat definitions are given for recording locations for species that are rare or limited in distribution in the province. Status is colour-coded in red, yellow or green. Contact: Biology Department, Acadia University. Wolfville, Nova Scotia B0P 1X0; Telephone (902) 585-1313.

Web site: http://landscape.acadiau.ca/herpatlas.

Recovery of Nationally Endangered Wildlife: *RENEW Report* Number 9, 1998/99

A 48-page booklet the Committee on the REcovery of Nationally Endangered Wildlife. Research, editing and production coordination are by West Hawk Communications. Research and coordination are by Mary Rothfels, Lisa Twolan and Simon Nadeau of the Canadian Wildlife Service. It includes species recovery updates for 26 animal and plant species, subspecies, or populations, and for one ecosystem. There are also lists of recovery teams, 1998 species at risk, status of renew plans, 1998 List of Canadian species at risk. It is available from Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, and also accessible on the web at http://www.cws-scf.ec.gc.ca/renew/index_e.html

A new searchable database on species at risk listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has been developed by Environment Canada (Canadian Wildlife Service), the Canadian Wildlife Federation, the Canadian Museum of Nature, and Natural Resources Canada, and is now accessible at: www.speciesatrisk.gc.ca.

FRANCIS R. COOK

Book-review Editor's Report, 1998 (Volume 112)

This has been an eventful year, including the first part of 1999, with more travel and international work, formation of my own company, editorship in a foreign journal, resident papers and a hopeful look at democracy in my second country. This again means an appeal to new and old reviewers to be patient while I am out of touch and to keep in touch with me when you are interested in reviewing books. Books are ever increasing in volume and price. During volume 112, we received 123 complimentary books from publishers. This is almost half of the 285 new titles listed. Only half of them were actually requested by prospective reviewers. This always creates a challenge since our reputation with the publishers depends on timely reviews. Of these books, 90 were sent to reviewers and 69 reviews published. Those who read the new titles and volunteer to review books are always welcome. Please contact me first and please request our guidelines to follow if you do not already have them.

WILSON EEDY

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Description of Ottawa Field-Naturalists' Club Annual Awards

MEMBER OF THE YEAR: In recognition of the member judged to have contributed the most to the Club in the previous year. (Members of the Executive are excluded from consideration.)

GEORGE MCGEE SERVICE AWARD: In recognition of a member (or members) who has (have) contributed significantly to the smooth running of the Club over several years. (Members of the Executive are excluded from consideration.)

CONSERVATION AWARD — MEMBER: In recognition of an outstanding contribution by a member (or group of members) in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

CONSERVATION AWARD — NON-MEMBER: In recognition of an outstanding contribution by a non-member (or group of non-members) in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

ANNE HANES NATURAL HISTORY AWARD: In recognition of a member who, through independent study or investigation, has made a worthwhile contribution to our knowledge, understanding and appreciation of the natural history of the Ottawa Valley. The award is designed to recognize work that is done by amateur naturalists.

PRESIDENT'S PRIZE: The President's own recognition of a member for unusual support of the Club and its aims.This award and any associated presentation is to be made, or not, at the sole discretion of the President.

HONORARY MEMBER: [Summarized here from the Ottawa Field-Naturalists' Club Constitution] This award is presented in recognition of outstanding contributions by a member or non-member to Canadian natural history or to the successful operation of the Club. Usually people awarded an honorary membership have made extensive contributions over many years. At the present time honorary membership is limited to 25 people.

Nominations can be made by any Club member for any of these awards except the President's Prize. Nominations and supporting rationale should be submitted no later than 15 December each year to: Awards Committee, The Ottawa Field-Naturalists' Club, Box 35069 Westgate Post Office, Ottawa, Ontario, K1Z 1A2

Nominators are asked to provide as much information as possible on their nominees. This will assist the Awards Committee and ensure that the nominees get the best consideration.

AWARDS COMMITTEE
Ottawa Field-Naturalists' Club

The Ottawa Field-Naturalists' Club 1998 Awards

The 1998 awards were presented at the annual Soirée held at the Unitarian Church in Ottawa on 23 April 1999. The awards are given to recognize and encourage contributions towards the goals of the club by individuals or organizations.

The Macoun Field Club is a club for young Ottawa area naturalists co-sponsored by The Ottawa Field-Naturalists' Club and The Canadian Museum of Nature since 1948. The presidents Chris Murray (Juniors), Lindsay Noël (Intermediates) and William Godsoe (Seniors) each spoke on the activities of their respective groups over the last year. Various members provided natural history exhibits and judges Mary Stuart and Connie Clark awarded First prize to Julian Potvin-Bernal for his display on caddis flies, Second, to Sara Potvin-Bernal for her display on animal behaviour and Third, to Alexander Wenzowski for his display on the behaviour of corvids.

Stephen Darbyshire read the citations for the 1998 OFNC awards and the president, David Moore, presented the framed certificates.

Member of the year – Robina Bennett

There are certain people who form a "backbone" in any organization to which they belong, always there when you need them, capably and efficiently undertaking a multitude of tasks, and, in ways too numerous to count, contributing to the group's overall success. Robina Bennett is one such person. Robina's contributions run wide and deep, spreading throughout a number of club activities, not only in the previous year, but over many years. Since 1986, she has been a core member of the team that ensures the smooth running of the OFNC Soiree. She is the Club's liaison with the Canadian Museum of Nature, organizing the monthly meeting space. She is a long-standing member of the Excursions & Lectures Committee. She has helped lead many field trips. When assistance is needed for special events, such as the Club's celebration of Bill Cody's 50 years as CFN Business Manager last year, Robina is there. With such an extensive background in Club activities, Robina is able to take on tasks and mobilize resources with great efficiently.

Robina is linked inextricably to the Fletcher Wildlife Garden, where she works tirelessly every Friday morning from April to October (always the first one there), offering ideas, advise and even her husband Ben! It is probably a safe bet to say that Robina's energy in whatever she undertakes, whether around the FWG or elsewhere, leaves most people feeling exhausted just by watching her! Robina has been involved with the FWG project from the beginning, attending some of those early meetings, finding and planting trees for the new woodlot and other plants for the Backyard Garden. She is also the efficient volunteer coordinator for all FWG activities. Too often at short notice Robina will be asked for help in rounding up bodies for clean-up days, weed-pulling parties, and various other events that sometimes suddenly arise. ... and she always comes through! Last year, 1998, was particularly busy. New volunteers are met by Robina who makes everyone feel welcome. And oh yes, she is the chief coffee-maker on Friday mornings, insisting that everyone takes a well-deserved break before heading back to work.

Therefore, for all of the above reasons, it gives us great pleasure to present Robina Bennett with the very well-deserved Member of the Year Award.

Honorary Member – Francis R. Cook

The Ottawa Field-Naturalists' Club presents Honorary Membership to people who have either made significant and distinctive contributions to natural history in Canada or who have made extensive contributions to the Club and its objectives. In 1960 Francis R. Cook came to Ottawa for a "permanent" appointment to the herpetology section of the National Museum of Natural Sciences (now called the Canadian Museum of Nature). Two years previously he had joined the Ottawa Field-Naturalists' Club. Since that time Francis has served both the Club and Canadian biology in a remarkable and distinctive way.

From 1960 to 1991, Francis was the curator of the reptile and amphibian collections at the museum and a leading figure in Canadian herpetology. He has continued his herpetological work to this day as an emeritus researcher at the museum. Apart from his own research work which has resulted in over 60 scientific papers, books and book chapters plus 120 miscellaneous contributions including book reviews, Francis is well known to students and other workers across the country for his enthusiastic encouragement and generous help in their work. His careful curation and diligent expansion of the museum's national collections during his career will serve as a legacy for the country and for researchers for years to come. To Club members Francis is well known for his excellent articles in Trail & Landscape: *Salamanders of the Ottawa District* (2: 18–21); *The Toads, Treefrogs and Frogs of the Ottawa District* (2: 50–56); *Turtles of the Ottawa District* (2: 82–87); *Lizards and Snakes of the Ottawa District* (2: 99–106); later updated with maps as *The Amphibians and Reptiles of the Ottawa District* (15: 75–107), and to a wider audience for his *Introduction to Canadian Amphibians and Reptiles* (National Museum of Natural Sciences, 1984).

The contributions that Francis has made to conservation in Canada were another important service to Canadian biology. He was an early instigator in the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and was chair of its amphibian and reptile subcommittee from 1980 until 1994. For twenty years he was a scientific advisor to the Canadian scientific and management authority for the Convention on International Trade in Endangered Species of wild fauna and flora (CITES).

The Club also recognizes a tremendous contribution by Francis as editor of *The Canadian Field-Naturalist*. For more than 22 years (1962–1966 and 1981-present: 90 issues) he has guided the production of the Club's scientific journal with a professional diligence and expertise. Between his stints as editor he served as Associate Editor for herpetology for an additional 9 years (1972–1981). Not only has this been a great service to the Club, but it has been a valued contribution to Canadian biology and conservation, providing an internationally recognized venue for the distribution of field research results. The ever-increasing size of the publication is a testament to the need for its unique focus and contributions.

For all those who have worked with Francis, perhaps the most important of his contributions has been his wonderful sense of humour which brings great pleasure without compromise to professional integrity.

Conservation Award (Member) – Ewen Todd

The Conservation Award - Member was established to recognize recent outstanding contributions to the cause of conservation in the Ottawa area. Ewen Todd's important contributions are not only recent but also extend back continuously for at least two decades.

Ewen has contributed to the Club's conservation activities throughout this period. He served as the chair of the Conservation Committee for three years in the late 1970s, after retiring as OFNC president, and then continued as an active and dependable member to the present. People rely on him for his experience and for his sensible suggestions on how to approach various problems.

In addition to Ewen's contributions through the Conservation Committee, he has represented The Ottawa Field-Naturalists' Club, bringing a conservation viewpoint directly to the greater community. During the past two decades he has been a member of various advisory committees set up to manage natural resources in Eastern Ontario. He is an original member of the Marlborough Forest Committee that has met several times a year since the early 1980s to advise the Regional Municipality of Ottawa-Carleton and the Ontario Ministry of Natural Resources on the management of the forest. He also belonged to a similar committee considering North Lanark forests and is still consulted on issues important to that area. In recent years Ewen has been involved with two committees designed to assist the Rideau Valley Conservation Authority: the Landowner Resource Centre and the Rideau River Biodiversity Project Community Advisory Group.

In all of these groups, Ewen has had to present the position of naturalists in relation to many other interests. He has pushed the case of the value of nature for its own sake without antagonizing landowners and those who see land as a resource to be exploited or as a source of pests, such as Coyotes, that have to be destroyed. During that time, the Ministry attitude has changed from one of forestry management for the benefit of foresters to a recognition that its mandate was broader than simply growing trees in order to chop them down. The fact that Ministry staff could come to the realization that they could actually manage some forest areas by essentially leaving them alone was quite an achievement, one in which Ewen played a part. In the three-year Rideau River Biodiversity Project, Ewen is encouraging committee members to take an active role in managing this water resource, because after the research is completed by the Canadian Museum of Nature, the community will have to take responsibility for ensuring that its biodiversity is not diminished.

Ewen's admirable record of service to conservation actually began in his native Scotland, from where he came to Ottawa in 1968. Scotland's loss has certainly been Ottawa's gain.

Conservation Award (Non-Member) – Jean Langlois

In its long history of conservation work, The Ottawa Field-Naturalists' Club has seen the appearance of many organizations which have contributed much to the appreciation of our natural environment and its protection. The assault on our natural areas and wilderness lands have increased steadily over recent decades. While the Club has done much for the cause of conservation, many other organizations and individuals have brought their own strengths and interests to the struggle.

For a number of years Jean Langlois has been a major organizational force in conservation issues in the Ottawa Valley. As the past volunteer President and now Executive Director of the Ottawa Valley chapter of the Canadian Parks and Wilderness Society (CPAWS) he revitalized and invigorated the Ottawa Valley chapter, strengthening the organization's links with its national organization and with other wilderness issue networks and coalitions. The CPAWS Ottawa Valley Chapter has recently started monthly meetings at the Canadian Museum of Nature at which Jean is the primary player. These meetings go a long way toward stimulating interest and discussing important conservation issues.

Quebec is the only province without a chapter of CPAWS, and Jean is applying his organizational and motivational skills to developing a Quebec-based group. Judging by his success with CPAWS-OV, it will not be long before a dynamic group emerges in Quebec.

Jean has worked incredibly hard on Ontario's Lands for Life issue. At a local level he has brought the issue to the fore by organizing meetings for the public and with local MPPs, making press releases, organizing letter writing campaigns and encouraging people to become involved. In just a few short weeks between the announcement of John Snobelen's consolidated recommendations and the November 30th deadline for public response, he wrote a 4-page flyer and organized a massive mailing campaign. This campaign proved immensely successful at informing the public and generated a huge response to the woefully inadequate proposals.

Jean and the Ottawa Valley CPAWS chapter, together with the Wildlands League, spearheaded the campaign whereby wilderness advocates stake "mineral" claims in the Temagami wilderness area, drawing public attention to the potential of mine development in the area and, maybe, preserving some land in a wild state. He was also instrumental at coordinating the work of a coalition culminating in a radically toned-down development of the Meech Creek Valley. As a result of this intervention some of the valley's land, previously unprotected, has been added to Gatineau Park.

With strong interests in Algonquin Park, Jean sits on the Algonquin Park and the Algonquin-to-Adirondack Committees of CPAWS-OV. The latter committee has grown from Jean's idea of promoting connectivity between the two parks and by preserving the as-yet undeveloped intervening landscapes remaining as wildlife habitat. An intriguing concept, behind which Jean is the driving force.

Highly effective in maintaining CPAWS-OV as an efficient and productive organization, Jean makes things work. Through this award the Club wishes to recognize his extensive energy, remarkable organization skills and enthusiastic leadership style.

AWARDS COMMITTEE
Stephen Darbyshire, Chair
Ottawa Field-Naturalists' Club

A Westward Trajectory Extension for the Earth-grazing Fireballs Seen on 9 February 1913

WILLIAM E. RICKER and JON T. SCHNUTE

Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia V9R 5K6, Canada

Ricker, William E., and Jon T. Schnute. 1999. A westward trajectory extension for the earth-grazing fireballs seen on 9 February 1913. Canadian Field-Naturalist 113 (4): 693–697.

A unique procession of several dozen fireballs, later called cyrillids, crossed much of southern Canada on 9 February 1913. We use data from historical sightings to extend the cyrillid trajectory westward from the path examined previously. Knowledge of this trajectory enables us to identify a previously unreported sighting made near Nanoose, British Columbia. There, possibly illuminated by the setting sun, the cyrillids made a brilliant and frightening display against a sky already dark.

Key Words: fireballs, cyrillids, trajectory, 1913, Nanoose, British Columbia.

In die illa tremenda quando coeli movendi sunt, et terra ....

The heavens are certainly part of Nature, though they are not often mentioned in the pages of the Canadian Field-Naturalist or its predecessors. However, *The Ottawa Naturalist* did include a lecture by J. S. Plaskell (1912) on the evolution of celestial objects. Although astronomy was not in the contents of 1913, it might well have been. On 9 February of that year, at about 9:10 p.m. Eastern Time, there was a display of lights in the skies of southern Canada the like of which has not been reported from anywhere else on earth, before or since. Fortunately accounts of these "fireballs" were collected and published by C. A. Chant of the University of Toronto (Chant 1913a, 1913b). There were several dozen of the objects, having various degrees of brightness, assembled in small groups that formed a long procession moving "slowly and majestically" across their starry background. Each fireball had a long luminous "tail", and it was estimated that the whole parade lasted about 3.3 minutes. Just as they disappeared, "a rumbling sound like distant thunder" was heard, and it rattled windows in houses below. Wherever they were seen, the fireballs seemed to be moving parallel to the earth's surface, with no recognizable change in altitude.

Most reports of this display came from Ontario, where the sky was clear and the fireballs were travelling across the well populated countryside from Clark Point on Lake Huron to Fort Erie on the Niagara River. New York and Pennsylvania were cloudy, but one sighting was made from northern New Jersey, not far from New York City. Unfortunately no scientist saw them, but Chant's collection of reports by observers from Saskatchewan to Bermuda makes fascinating reading. Additional records have been assembled by John O'Keefe of the National Aeronautics and Space Administration near Washington, D. C. These include a newspaper report from Didsbury, Alberta (between Calgary and Red Deer), several sightings from Minnesota to Michigan, and some from ships at sea, one as far south as 3° below the equator off northeastern Brazil (O'Keefe 1961, 1968).

The fireballs were given the name "cyrillids" by O'Keefe, because they were seen on St. Cyril's Day. The name seems appropriate for another reason. There were two St. Cyrils, both of them bishops who were fiery disputants in the ecclesiastical controversies of their times (4th and 5th centuries).

In Ontario the cyrillids were between 35 and 48 kilometres above the earth, according to Chant (1913a, pages 154–155). He derived his estimates by triangulation, using angles from observed positions in the sky relative to background stars and known baseline distances from observers to the cyrillid path. He estimated the largest ones to be 30 metres or more in diameter, based on observed sizes relative to a full moon. Although they appeared to move rather slowly across the sky, he concluded from distances and timings between sightings that they were actually travelling between 8 and 16 km per second. This would get them from coastal British Columbia to the Niagara River in 4 to 8 minutes.

O'Keefe (1961) describes how it is impossible that the cyrillids could have travelled through space as a swarm of small objects. Instead, they must originally have been a single body that was captured by the earth and swung into an orbit around it. On a much larger scale, in 1994 the comet Shoemaker-Levy 9 was captured by Jupiter and broken into a series of 21 bright objects, of which the Hubble telescope's spectacular photographs appeared in many

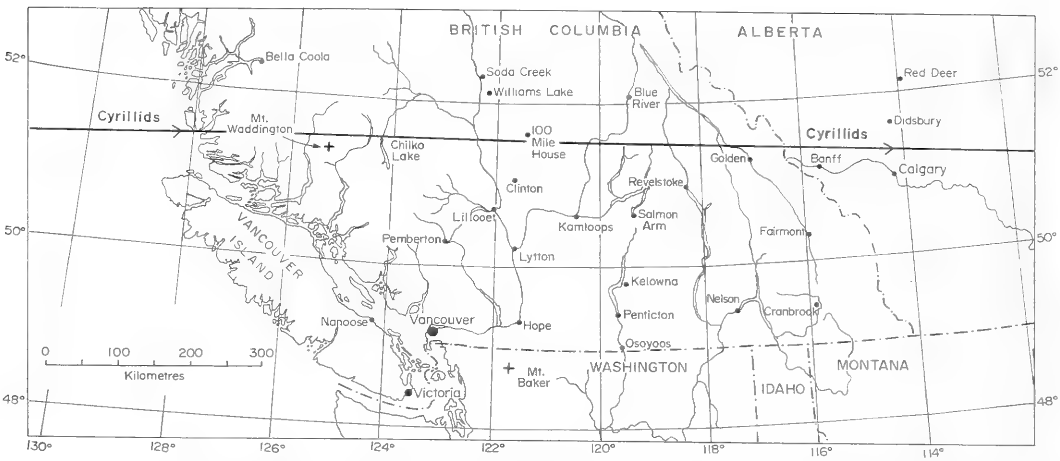

FIGURE 1. Path of the cyrillid fireballs across British Columbia and western Alberta. In this projection the parallels of latitude are curved, and the path of the cyrillids is almost straight.

magazines. Levy et al. (1995) say that this fragmentation was accomplished by Jupiter's gravity as the comet made a close turn around the planet. It seems doubtful that the cyrillids' parent body would have been large enough to be shattered by the earth's gravity. As suggested to us by a reviewer, it may have fragmented from ram pressure on entering the earth's atmosphere, perhaps breaking along pre-existing flaws.

Using "the formulas of spherical trigonometry", Chant computed the surface "trace" of the cyrillids eastward and southward from Pense, Saskatchewan (27 km west of Regina, at 104.98° West, 50.42° North), where they were said to be directly overhead. His calculation also depended on a second point derived from Ontario sightings centred on 80.00° West, 43.40° North, 25 km northwest of Hamilton. The fireballs moved along a great circle course around the earth's spherical surface, one that begins to trend south of east over western Canada. Chant (1913a, Figure 2) shows this course from Saskatchewan eastward. For a westward extension, we used the two points cited above to express the great circle course in terms of latitude ϕ ($-90° \leq \phi \leq 90°$) and longitude θ ($-180° < \theta \leq 180°$), as follows:

$$\tan \phi = -0.65734 \cos \theta - 1.07615 \sin \theta . \qquad (1)$$

(Positive and negative latitudes ϕ correspond to North and South, respectively. Similarly, positive and negative longitudes θ are East and West of 0°.)

From this formula, the cyrillids reached their most northerly position at 51.59° North and 121.42° West, a few kilometres from 100-Mile House in the Cariboo region of British Columbia (Figure 1). They got there from slightly south of west, along a line that crossed Queen Charlotte Sound a little north of Vancouver Island. They then passed near Mt. Waddington, the highest peak in the Coast Mountains, but were of course far above it.

Did anyone in British Columbia see these fireballs? We searched available indexes of Vancouver and Victoria newspapers for February and March of 1913, but found nothing about unusual lights or sounds. The files of the Nanaimo *Free Press* and Courtenay *Islander* were similarly unrewarding. However, we put a note (Ricker 1991) in the *British Columbia Historical News* asking for information. The only reply came from Mrs. Peggy Nicholls of Nanaimo. She had not seen the fireballs herself, but described an earlier conversation with Mildred Kurtz. Mrs. Kurtz was the daughter of Ernest John Marks, who came to British Columbia in 1912 and settled near Nanoose, about 20 km northwest of Nanaimo. At some time during the ensuing two years, the family observed a remarkable display of lights in the sky. Mrs. Kurtz is no longer living, but Mrs. Nicholls' recollection of the conversation is as follows:

> On the night in question Mr. and Mrs. Page were visiting them. Mr. Page was supposed to be writing a book. In telling (I wrote the notes down at the time) Mildred said there was an awesome display of lights and sounds. "It's the end of the world", declared Mr. Page, "now I'll never finish my book" — and he began to pray. Mildred said she was very frightened by Mr. Page, but told me she still remembers the brilliance of that night sky and that she never saw anything like it again. From the timing I would think that Mildred was about 6 years old. She died a few years ago. It could have been a much discussed family item .... I would think that Mildred would have been familiar with northern lights, as we called them, for there was often a good display at Nanoose.

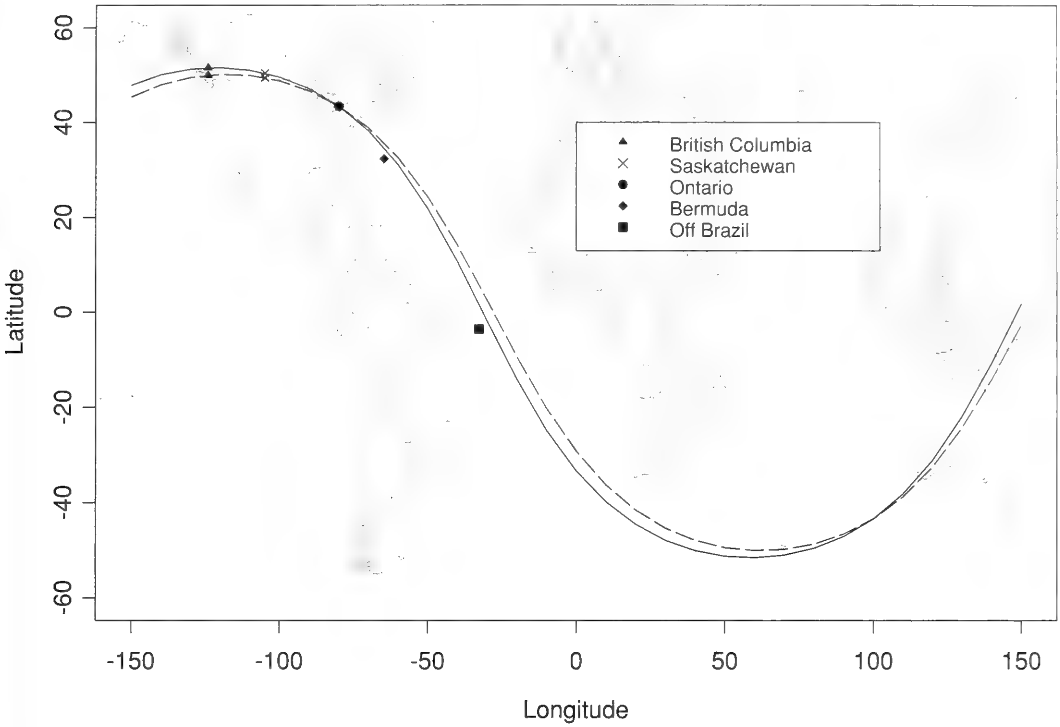

FIGURE 2. Global trajectory (solid line) of the cyrillids, computed from (1), compared with the alternative trajectory (2; broken line), based on moving the Saskatchewan sighting 1° south.

Mrs. Nicholls also sent a map showing that, at the time of the display, the Marks family was living on a farm adjacent to the Esquimalt and Nanaimo Railway, where it crosses the road to Northwest Bay for the third time after leaving the Arlington station at Nanoose. This site (124.16° West and 49.28° North) offers a clear view of the northern sky and is approximately 260 km south of the computed trace of the cyrillids shown in Figure 1.

At about 42 km above the earth, the cyrillids were seen at places up to about 350 km from their trajectory, for example at North Bay, Ontario. At a distance of 260 km they would be 9.2° above the horizon. Using the apparent shape of the firmament shown by Chant (1913a, Figure 3), they would appear to be well up in the sky, about 40% of the apparent vertical distance from ground to zenith. However, the description of the Nanoose display has features somewhat different from those observed farther east. For example, no long tails are mentioned, and the whole effect seems to have been much brighter. O'Keefe, who initiated the search of western Canadian newspapers that turned up the account from Alberta, did not extend the search into British Columbia because "at around 6 p.m. local time the fireballs would have been obscured by sunlight". Actually it is already completely dark nearly everywhere in British Columbia at 6:10 p.m. on 9 February. Even in the southwestern coastal region, it is dark enough for the brighter of the fixed stars to be seen. The official sunset there is at 5:26 p.m. Pacific time, but at the Marks family's site the sun would have disappeared somewhat earlier behind the island mountains. Objects 42 km above the earth would still have been brightly illuminated by a sun that, for them, had not yet settled into the Pacific Ocean. Furthermore, at this point in their orbit, the cyrillids may have been even higher than they were later over Ontario. Thus, in British Columbia, they may have been visible by reflected sunlight as well as their own luminosity.

One of us (WER) remembers watching the discarded booster stage of Sputnik II at Nanaimo, as it travelled across the evening sky over Mt. Benson. What he actually saw, of course, was the sunlight reflected from it, waxing and waning as the booster slowly rotated. This was not a large object, and it was at least 300 km distant, yet it seemed about twice as bright as Venus is at its brightest phase. The cyrillids were at a similar, though more nearly horizontal, distance from Nanoose. Having diameters up to 30 metres or more, each of them must have shone many times more brightly than Venus does, or than the Sputnik booster did. A series of lights of this brilliance, moving across a dark sky, could easily evoke a fearful apprehension that the last days of the world had come.

While it is easy to understand a sighting of the cyrillids from Nanoose, it is less easy to explain the sounds mentioned in Mrs. Nicholl's account. Each cyrillid must continually have produced a loud sound, similar to that from a supersonic aircraft, but under somewhat different circumstances. The cyrillids moved at about 35 times the speed that sound has at the earth's surface, which is a great deal faster than any aircraft goes. They also travelled at a greater altitude, where the air is more rarified. The sound, travelling at about 20 km per minute, would require about 13 minutes to reach Nanoose at a minimum distance of 260 km from the cyrillids' path. Whether the sound would be audible at that distance is conjectural, although the explosion of Mt. St. Helens was heard 800 km away (Fairfield and Galen, no date), for example at Bowron Lake in British Columbia. In any event, there were numerous cyrillids, each making a noise. Interference patterns from these sounds could possibly accentuate and diminish the collective effect. If the sounds mentioned in Mrs. Nicholl's account were of cyrillid origin, they would first have been heard about 10 minutes after the last cyrillid had passed.

Perhaps the cyrillids came closer to Nanoose than would be indicated by the orbital equation (1). Following Chant (1913a), we obtained this trajectory from two points on the earth's surface, corresponding to sightings in Saskatchewan and Ontario. Errors in the coordinates of these locations induce corresponding errors in the entire trajectory (Figure 2). For example, if the latitude of the Saskatchewan sighting is moved 1° south, leaving the Ontario point fixed, then the orbit over these two points is given by

$$\tan \phi = -0.55917 \cos \theta - 1.05884 \sin \theta . \qquad (2)$$

This passes the Nanoose longitude (124.16° West) at latitude 49.96° North, about 1.6° south of the corresponding latitude on trajectory (1). In fact, trajectory (2) passes over central Vancouver Island and comes within about 75 km of Nanoose. We use this example, not to argue that (2) is correct, but rather to illustrate potential errors in (1) that can result from uncertain positions of historical sightings.

Chant (1913a) demonstrated remarkable acumen in deriving numerical estimates of the trace, height, speed, and size of the cyrillids, based on fortuitous observations. He pointed out that "the observations are very discordant", leading to uncertain estimates. Since that time, the physical science of objects entering the earth's atmosphere has advanced considerably. A reviewer of our paper questioned the reported elevation, size, and speed of the cyrillids. For example, current science indicates that large objects become luminous at 80 km altitude and disintegrate rapidly at 35 km. Furthermore, an object as large as 30 m in diameter would probably have attracted more attention than the cyrillids did. Both Chant and the referee note that the apparent diameter can exceed the true diameter, due to gaseous luminosity around the core.

What happened to the cyrillids? On a hypothetical subsequent circuit of the earth, which would occur about an hour after the observed one, they would be several hundred kilometres south of their previous position over central North America because of the earth's rotation. O'Keefe (1961) made a wide search for reports of their occurrence in the United States at that time, but discovered none. Several observers in Ontario reported that they saw a fireball explode, and the long "tails" suggest an active process of disintegration. Cyrillid fragments probably reached the earth somewhere on the route shown in Figure 2, most likely in the ocean where no recoveries were possible.

As for the display at Nanoose, we would like to have a precise date for it, or a living witness, in order to be completely sure that what the Marks and Page families saw were really the cyrillids. The quotation above indicates that the display could not have been any of the usual phenomena seen in the sky. As Mrs. Nicholls pointed out, it was not the aurora. A thunderstorm, no matter how violent, is too familiar an occurrence to suggest that the end of the world has arrived. Whatever the families saw, it was a unique heavenly exhibition of some sort, which deserves to be recorded on its own merits. In our opinion, however, it would be too great a coincidence to have had *two* unprecedented, yet unrelated, celestial displays occurring at about the same time early in the twentieth century.

Acknowledgments

We are greatly indebted to Mrs. Peggy Nichols, a member of the Nanaimo Historical Society, for providing the information concerning the celestial display near Nanoose. Librarians at Malaspina University-College in Nanaimo and the Courtenay Museum assisted our search for historical newspaper references. Karl Ricker supplied details about the Mount St. Helens explosion. An anonymous reviewer provided valuable information on the physics of fireballs.

Literature Cited

Chant, C. A. 1913a. An extraordinary meteoric display. Journal of the Royal Astronomical Society of Canada 7: 145–215.

Chant, C. A. 1913b. Further information regarding the meteoric display of February 9, 1913. Journal of the Royal Astronomical Society of Canada 7: 438–447.

Fairfield, C. M., and **C. Galen.** No date. OMSI sound project. Oregon Museum of Science and Industry, Portland, Oregon. 1 page.

Levy, D. H., E. M. Shoemaker, and **C. S. Shoemaker.** 1995. Comet Shoemaker-Levy 9 meets Jupiter. Scientific American, August 1995: 84–91.

O'Keefe, J. A. 1961. Tektites as natural earth satellites. Science 133: 562–566.

O'Keefe, J. A. 1968. New data on cyrillids. Journal of the Royal Astronomical Society of Canada 62: 97–98.

Plaskell, J. S. 1912. The evolution of the worlds. Ottawa Naturalist 26: 29–34; 52–60.

Ricker, W. E. 1991. Meteors over B. C. in 1913. British Columbia Historical News, Spring 1991: 32.

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Book Reviews

ZOOLOGY

Habitat Characteristics of Some Passerine Birds in Western North American Taiga

By Brina Kessel. 1998. University of Alaska Press, Fairbanks. 117 pp., illus. U.S. $16.95.

In 1980 and 1981, Brina Kessel and seven field workers carried out an intensive study of the Upper Susitna valley, a large, undisturbed, roadless area, roughly halfway between Anchorage and Fairbanks. Expensive helicopter access was provided by the Alaska Power Authority to study the potential effects of a proposed dam and resulting flooding. Although that hydroelectric project died a merciful death on the drawing board, it had provided Brina Kessel the opportunity to measure habitat variables and to allow study of the habitat preferred by each of fifteen major bird species. The portion of valley studied was 100 km long. Each of 12 habitat types was represented by a 10-hectare study plot, and each of them in turn was divided into 49 0.2-ha subplots. Both years, eight bird censuses were done. Extensive statistical analysis produced specific information about habitat preferences, and allowed Kessel to conduct cluster analysis. Examples of interesting pairings of species in very similar habitat were: the Northern Waterthrush and Black-capped Chickadee, Ruby-crowned Kinglet and Gray Jay, White-crowned Sparrow and Wilson's Warbler, and Gray-cheeked Thrush and Fox Sparrow. Threesomes of species with close habitat similarities were Yellow-rumped Warbler, Swainson's Thrush, and Common Redpoll, and Tree Sparrow, Savannah Sparrow, and Arctic Warbler.

In the cold-dominated Alaskan taiga near latitude 63° fewer tree species and forest types occur than is the case farther east in North America. Habitat preferred by bird species also differs from those of the same species in mid-continent. Blackpoll Warblers in the Alaskan taiga are mainly in deciduous habitats (in contrast with northern Saskatchewan, where they prefer coniferous habitats).

There is a colour photograph of each of the 15 main bird species and 13 habitat photographs in black-and-white. The University of Alaska Press subcontracted this book to University of Toronto Press; both can be proud of a well-illustrated and unusually attractive product.

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BC Wildlife: Selected British Columbia Mammals, an Interactive CD-ROM

Developed by C. W. Chestnut, L. Hammond-Kaarremaa, and D. Salisbury. 1998. British Columbia Ministry of Advanced Education, Training, and Technology (distributed by Raincoast, Vancouver). 566 Mbt. $34.95.

Having been involved in both the development of web sites and CD-ROMs depicting environmental data, I have supported the idea of replacing books with CDs. They are much easier to carry, for those of us that work in exotic places, and provide the multimedia advantages of interlinking sight, sound, and words. This is the first one that I have had the opportunity to review and I was both impressed and unhappy.

I will both offer my congratulations and some, hopefully constructive, criticisms. To start off, the CD covers only mammals and then only "over 40 .... of BC's higher profile mammals". The information on taxonomy, identification, feeding, habitat, behaviour, and reproduction is well presented and concise. I would class it as upper secondary or lower college level. There is not a lot of detail and, with the exception of some excellent and dynamic links to web sites, I found only one reference to further sources. I think a good bibliography or further detailed text would have helped. In fact, the web sites would seem to provide more information than the CD.

Among the most impressive resources are the photographs included. Most are high-resolution *.bmp images which require 300 to 3000 Kbt each. Some species are possibly over-represented and I think it would have been nicer to put in more information and perhaps use smaller image formats. Also, it would have been nice to have some of the *.wav files as animal sounds, not just how to pronounce technical terms. The roar of the cougar, at the start, had me expecting more.

I must admit that I became a little frustrated when I repeatedly had to go back to the start to get into new sections. I later discovered that this was a technicality as the program kept loading my window at the bottom of the page so that the menu was off the screen. It would have been nice to allow a little more interactive technology, such as clicking on a picture to see more about the animal. This did work rather better in the taxonomy section.

The distribution section was only in British Columbia. Admittedly that was the topic, but a small global distribution map would have been helpful. Few species follow political boundaries. The conservation status section was interesting, but could have offered more detailed definitions, references, or information on sources. I was given the impression that the "Red List" was developed by the BC Government. Is this the same as the list used by COSEWIC or CITES or other international groups?

In general, I support the idea and this particular CD, especially for school use. I do think that the CD will have to offer more if it is to compete with web sites which are free, usually much more dynamic, and much more detailed.

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Rapport sur la situation de la rainette faux-grillon de l'ouest (*Pseudacris triseriata*) au Québec

Par Jöel Bonin et Patrick Galois. 1996. Ministère de l'Environnement et de la Faune, Québec. vii+39 pp.

Despite the fact that surveyed boundaries are credited with much of the ecological damage commercial people have inflicted on North America (William Cronon, 1983. *Changes in the Land: Indians, Colonists, and the Ecology of New England*. Hill & Wang, New York. xiii+241 pages), one sometimes feels that conservationists, and the agencies that sponsor them, think we can overcome these problems by producing ever-more categories and boundaries. If there is a calculus-like limit theorum at work here, it does not seem to have been formally expounded, but it sometimes seems to be a core assumption of the conservation and endangered species movements.

The process that led to the present document is severely constrained by boundaries. The report is a workmanlike example of its genre: the status assessment written into a prescribed format. It concludes that "Recent studies show a decline of the species in the region south of Montréal where only a few relict populations remain. Major causes of this decline are probably modification and loss of habitat due to intensification of agriculture and urban development. In the Outaouais Valley, where the species is more common, habitat loss has been limited. The long-term future of the Western Chorus Frog, however, depends on the perpetuation of existing habitat conditions" (authors' English abstract).

Two sets of boundaries make the studies that provide the data for this report unsatisfactory, and unlikely to lead to a full understanding of its causes. The first is geographical. The biological problem addressed is the decline of Chorus Frogs in the St Lawrence and Ottawa valleys since the 1950s. The area considered is restricted to the limits of the province of Quebec, though the problem (to judge by my surveys in the 1970s and 1990s) extends to southern Renfrew County and Kingston in Ontario, to Burlington in Vermont, and to Plattsburg and Pulaski in New York. Secondly, the reason the problem has been studied in Quebec, and not in Ontario, is that the peripheral character of the Quebec populations entitles them to special status as a potentially "endangered" species. While declines in eastern Ontario (and in New York) have been, in my opinion, equally great, the perceived continued abundance of Chorus Frogs elsewhere in southern Ontario has resulted in official indifference to their fate in eastern Ontario (I discovered the species in Vermont in 1975, and now it is evidently extirpated there).

Because anuran meta-populations fluctuate widely, we can only understand the reasons for their declines while they are still abundant enough to escape classification as "endangered." While it is nice to get government support for the study of endangered peripheral populations, such studies, if they are to hope to reach a full understanding of the declines, must extend to the biological limits of the decline, not be cut off at the political boundaries of the sponsoring jurisdiction. I don't know if it's practical to expect boundary-minded bureaucracies to support studies outside their territory, or of declining and fluctuating species too abundant to fit into legislated categories of rarity, but naturalists must do all they can to study real problems, even if these don't fall neatly into arbitrary formal categories.

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[with help in translation from ANITA MILES]

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Encyclopedia of Reptiles and Amphibians: A Comprehensive Illustrated Guide by International Experts

Consultant Editors Harold G. Cogger and Richard G. Zweifel. 1998. Second edition. U.S. Publisher Academic Press, A Division of Harcourt Brace & Company, San Diego, California. 240 pages, illus. U.S. $34.95

The dust jacket alone marks this 316 × 246 mm volume as an arresting coffee table display. A head and forebody photograph identified as an Eyelash Viper, *Bothriechis schlegeli*, on a scarlet bromeliad against a black background dominates the front, and a 114 × 96 inset of a red-eyed, orange-toed, green head-and-bodied with blue on the interior leg surfaces, Central American Red-eyed Treefrog, *Agalychis callidrays,* on a scarlet background is the back.

In vividness, content matches dust jacket. More than 200 photos from a variety of individual contributors are spread over the first 233 pages, effectively representative and breathtaking in their fine texture and sharp colours. To supplement them, there are an additional 100 illustrations in colour by David Kirshner, mostly portraits of individual species but a few diagrams of structures are also included. The portraits, although painstakingly created, seem to lose effect when interspersed with the even more detailed photographs, and perhaps would have been more effective somewhat reduced in size.

Overall it is a persuasive argument for redoubled efforts toward the world conservation of these forms, once loathed with fervour because of real and imagined toxicity and dismissed as insignificant frequenters of damp unhealthy places with little economic importance to humans and negligible diversity. However, their beauty and the fascination in their subtle and surprising variation in morphology, adaptations, and behaviour is increasingly recognized. Not only would the world be a less attractive place should many of these forms vanish before the onslaught of our gross exploitation of the landscape, but their loss would serve as yet another telling signal of the rapidness with which we are laying our precious natural inheritance to waste.

The accompaning text is succinct and effective although it hits highlights rather than being comprehensively encyclopedic. It opens with brief appeal for conservation by George B. Rabb, Director of the Brookfield Zoo and Vice-Chairman of the IUCN Species Survival Commission. Following are three major parts, each consisting of individually authored sections by herpetologists from a number of countries, a diversity that is unique to this volume among general texts. Part one, The World of Reptiles & Amphibians consists of Introducing Reptiles and Amphibians (Harold G. Cogger, Australian Museum, Sydney, and University of Newcastle, Australia), Classifying Reptiles & Amphibians (Jay M. Savage, University of Miami, Florida, USA), Reptiles & Amphibians through the Ages (Oliver C. Rieppel, Field Museum of Natural History, Chicago, USA), Habitats & Adaptations (William E. Duellman, Curator Emeritus, Museum of Natural History and Professor Emeritus, Department of Systematics and Ecology, University of Kansas, USA; and Harold Heatwole, Department of Zoology, North Carolina State University, Raleigh, USA), Reptile and Amphibian Behaviour (William E. Duellman and Charles Carpenter, Professor Emeritus, University of Oklahoma and Curator Emeritus, Oklahoma Museum of Natural History, USA), and Endangered Species (Brian Groombridge, Biodiversity Assessment Programme, World Conservation Monitoring Centre, Cambridge, England). Part two, Kinds of Amphibians, contains Caecilians (Ronald A. Nussbaum, Professor of Biology and Curator of Amphibians and Reptiles, Museum of Zoology, University of Michigan, USA), Salamanders & Newts (Benedetto Lanza, formerly Director of Zoological Museum "La Specola" and Professor of General Biology, University of Florence, Italy, Stefano Vanni and Annamaria Nistri, Zoological Museum, "La Specola) and Frogs and Toads (Richard G. Zweifel, Curator Emeritus, Department of Herpetology and Ichthyology, American Museum of Natural History, New York, USA). Part three, Kinds of Reptiles, contains Turtles & Tortoises (Fritz Jurgen Obst, Curator of Herpetology and Vice-Director, State Museum of Zoology, Dresden, Germany), Lizards (Aaron M. Bauer, Professor of Biology, Villanova University, Pennsylvania, USA), Snakes (Richard Shine, Professor in Evolutionary Biology, University of Sydney, Australia), Amphisbaenians (Carl Gans, Adjunct Professor of Zoology, University of Texas, Austin, Texas, USA), Tuatara (Donald G. Newman, Science, Research and Information Services, Department of Conservation, Wellington, New Zealand), and Crocodiles & Alligators (William E. Magnusson, Instituto Nacional de Pequisas da Amazonia, Brazil). The book concludes with Further Reading (a sparse 72 entries, often to text-book overviews, but a few original scientific papers are included), Index (5 pages of small print), and Acknowledgments (6 lines).

The special emphasis on conservation is evident throughout. Each major group begins with a sidebar "Conservation Watch" giving the number of species endangered, threatened, and vulnerable. Although Groombridge points out that only 110 species of vertebrate animals are reliably known to have become extinct in the 20th century (the majority of these are presumably in the better documented groups, birds and mammals) this is virtually certain to accelerate as ever more species are reduced to increasingly vulnerable tiny population fragments. Interestingly, momentarily there is actually a steady increase in the number of new species documented that more than offsets the species documented as lost. Savage estimates here that during the past decade about 80 new species of amphibians (mostly frogs and toads) and 25 species of reptiles (mostly lizards) have been described each year, and the ever-increasing totals given are about 4 950 species of living amphibians and 7 400 species of living reptiles, in contrast to birds with 9 000 species and mammals with 4 670. But the rate of new finds may be horribly deceptive as much is due to fragmentation of habitat leaving increasingly small more-easily surveyed bits in which previously overlooked forms are more readily found, and the improved accessibility of such bits with new roads, modernized transportation, and, in a few cases, even improved political situations (Vietnam is a case in point where fresh intensive inventories recently have become practical). The discovery of new species is also inflated by revised species definition and new techniques, particularly in molecular analysis, leading to many former "composite species" being split into two or more forms, and many former subspecies raised to species status.

The first edition of this volume was published in 1992, and it should not be confused with a similarly titled, also excellent and well-illustrated, multi-contributor, earlier (1986) *The Encyclopedia of Reptiles and Amphibians* with different editors (Kraig Adler and Tom Halliday) and publisher (Facts-on-File, New York) which was also in a coffee-table format.

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The Life of Birds

By David Attenborough. 1998. Princeton University Press, Princeton. 320 pp., illus. U.S.$29.95.

This must be one of the best-illustrated general bird books ever produced. As well as the superb quality of reproduction the photographs capture dozens of examples of bird behaviour which have only been described before. One double-page photo is particularly beautiful. It was taken from a ridge on South Georgia Island in summer, looking down on a quarter of a million King penguins, adults and chicks, standing among scattered green shrubs on the edge of the sea. They are a "sea" themselves.

The Life of Birds is the companion volume to the series of the same name to be shown on PBS television and it promises to be outstanding. The filming by the BBC Natural History Unit took over two years and the crew travelled all over the world. David Attenborough's text meets the high standard we have come to expect from him. He has an ability to convey a great deal of essential information precisely and succinctly, knitting small bits of information together into a cohesive picture, so that at the end of a chapter the reader has a clear understanding of the subject. Fossil records from around the world are the basis for the first chapter "To fly or not to fly" and it traces the possible evolution from the *Archaeopteryx* ancestor to the current hypothesis of the split which produced gliding frogs and lizards, flying squirrels, and birds. In particular, the evolution of feathers is described: the base of both scales and feathers is very similar. There is new information on flightless birds, past and present, of which there were many more species then than today. Subsequent chapters on food, fishing birds, meat eaters, song, and breeding include some of the very latest scientific findings. The last chapter, "The Limits of Endurance" describes how birds have colonized the globe more effectively than any other vertebrate, adapting to Antarctic winters and African summers, and the challenges they have faced and are facing in order to survive.

There is no bibliography, perhaps because the sources would have filled half the book, but the text and chapter subjects make finding information easy, and there is an index.

The subjects have been covered in many other books, but there is a synthesis here which gives a real understanding of the subjects. The text is aimed at general readers with an interest in nature, but there is a great deal to interest those more knowledgeable. It is more than a pretty face.

JANE ATKINSON

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Status and Conservation of Midwestern Amphibians

Edited by Michael J. Lannoo. 1998. University of Iowa Press, Iowa City. xviii +507 pp, illus.; cloth U.S.$49.95; paper U.S.$29.95.

Publications on the status of amphibians for a particular area are becoming increasingly common because of the growing concern over global declines in amphibians. Canada has led the way, with two such publications (Bishop and Pettit 1992; Green 1997). This new volume is the first for any US region, focussing on eight states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Consisting of 42 papers, the book is divided into six major sections: Landscape Patterns and Biogeography, Species Status, Regional and State Status, Diseases and Toxins, Conservation, and Monitoring and Applications.

Many of the papers in the sections on Species Status and Conservation are the most interesting, providing detailed information on species or conservation issues. The editor, Michael Lanno, argues convincingly that effective management must be based on the awareness of naturally fluctuating hydrological conditions. Breeding will be unsuccessful in many wetlands during dry years and this can be catastrophic for populations in highly fragmented habitats. This is particularly true for short-lived species, such as Blanchard's Cricket Frog (*Acris crepitans blanchardi*) which undergoes a complete population turn-over approximately every 16 months. Blanchard's Cricket Frog is an appropriate symbol for this book: once one of the most abundant frogs in many states in the area, it has virtually disappeared from the upper half of the Midwest (as well as extirpated from Ontario).

Although any book which attempts to bring together current information on a group of organisms from a particular region is commendable, this hefty volume is lacking on several aspects. There is no single map that illustrates the entire area of interest and labels the states. The editor has also opted for only a single literature cited section at the end of the book. While undoubtedly there is a large degree of overlap among papers, it is more useful if the references cited are at the end of each paper.

More substantive problems arise in the content — or its lack. The section on Regional and State Status should be the core of the book providing an overview for each of the states and the entire region as a whole. While many states do have good summaries of existing knowledge only six of the eight states are represented. Even more frustrating is that some state accounts are as fragmented as the landscape they examine. For example there are three separate papers on Ohio or portions of the state. And there is no attempt to summarize the entire Midwest. While it is inevitable that books such as this represent a kind of conservation pot-luck, it is unfortunate that the editor was not able to solicit a few more entrees to round out the menu.

Despite these criticisms this is an essential volume for anyone interested in the status of amphibians in the Great Lakes area. It provides a wealth of information on state status, population trends and historical anecdotes and will undoubtedly help focus attention on amphibians and wetlands in general.

References

Bishop, C. A., and **K. E. Pettit.** *Editors*. 1992. Declines in Canadian amphibian populations: Designing a national monitoring strategy. Occasional Paper Number 76. Canadian Wildlife Service. 120 pages.

Green, D. M. *Editor*. 1997. Amphibians in decline: Canadian studies of a global problem. Herpetological Conservation, Number One. Society for the Study of Amphibians and Reptiles. 338 pages.

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BOTANY

Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination

C. C. Baskin and J. M. Baskin. 1998. Academic Press, San Diego. 666 pp. U.S.$99.95.

Seeds has been written with over 30 years of experience contributed by each author. The Baskins have targeted novices in the field of seed germination with a comprehensive overview of ecology, biogeography, and evolution and researchers, with a look at the state of knowledge.

The information is provided in 12 chapters. The chapters range in content from general introduction to germination ecology of specific ecosystems. Specialized life cycles and habitats as well as evolutionary aspects of seed dormancy are dealt with. The information can be easily referenced using the table of contents with its detailed subheadings, or from the taxonomic and subject indexes. Reference lists are supplied at the end of each chapter. Material is referenced from around the world.

Anyone familiar with this field of research should appreciate the vast amount of information available in this text. It will be a reference for many years to come. *Seeds* will provide the novice immediately a comprehensive look at literature on seed ecology, biogeography, and dormancy. This is a text well worth reading and retaining as a reference for those interested in seeds.

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Ontario Plant List

By S. G. Newmaster, A. Lehela, P. W. C. Uhlig, S. McMurray and M. J. Oldham. 1998. Ontario Forest Research Institute, Ontario Ministry of Natural Resources, 1235 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5. Soft, $32.10 (GST included) + $2.50 shipping. (Available from: Natural Resources Information Centre, Ministry of Natural Resources, P.O. Box 7000, 300 Water St., Peterborough, Ontario K9J 8M5).

This work is a printed version of the Ontario Plant List digital database which will be available as a Microsoft Access Version 7.0 for Windows '95 format from the Sault Ste. Marie address above at a cost of $30.00.

Because it is designed for digital use this volume does not have consecutive paging but is set up as follows:

Table of Contents

For those using a computer, they can push the right key to bring up a particular species on the screen, but for those using this book they must use the index either to the scientific or common name, if there is one. When either a computer operator or individuals using this book arrive at the page on which the species they are interested in is located, they will find the same information that would be found on the computer screen for that species: family, genus, species, up to 4 synonyms, English and French common names, and some or more of the following: LIFEFORM CODE, LIFECYCLE CODE, VEGETATION ALPHA CODE, OPL RECORD, WEED CONTROL ACT STATUS, MEDICINAL VALUE, BAYER CODE, STATUS CATEGORY, GRANK, SRANK, COSEWIC STATUS, MNR STATUS, and NRVIS CODE. These are always found in the same place on the screen or in the text. In order to be able to understand what is on the "screen" the user must first become familiar with the Rare Plants in Ontario and How to Use this Book sections.

This book contains a mass of useful information on the mosses, lichens and vascular plants of Ontario which can readily, at least on the digital database, be updated and is already a step ahead of Morton and Venn (1990) with such additions as *Carex juniperorum* and three varieties of *Panicum acuminatum*. Undoubtedly there will be updated editions as knowledge of the flora of Ontario progresses. It has taken a great deal of effort to reach this stage, keep up the good work.

WILLIAM J. CODY

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Plants of British Columbia, Scientific and Common Names of Vascular Plants, Bryophytes, and Lichens

By Hong Qian and Karel Klinka. 1998. UBC Press, 6344 Memorial Road, Vancouver, British Columbia V6T 1Z2. 534 pp. $135.00 + 7% GST + $5.00 shipping.

Following a short introduction, this volume is divided into three sections: Part 1 – Systematic Lists of Scientific Names, Part 2 – Alphabetical List of Scientific Names, and Part 3 – Alphabetical List of Common Names.

The Systematic List of Scientific Names is divided into three sections: Vascular Plants, Bryophytes, and Lichens. In each of these sections the families are listed alphabetically and within them the accepted genera, species, subspecies, and varieties are alphabetized in **bold face** with synonyms in *italics* following the accepted names. Synonyms are also included in the alphabetical list followed by the accepted name (*Sagittaria esculenta* T. J. Howell = *Sagittaria latifolia* Willd.). A unique acronym in square brackets follows each accepted genus, species, subspecies, or variety, which in turn is followed by a single common name, if one is known. The accepted scientific name of an introduced plant is preceded by an asterisk*. Each family name is followed in brackets by a letter indicating in which of the major plant groups it can be found (V = vascular plants, B = bryophytes, and L = lichens) and the vascular plants and bryophytes are further divided into smaller groups V (G = gymnosperms, D = dicots, M = monocots) and B (M = mosses, H = hepatics).

The Alphabetical List of Plant Names is strictly alphabetized with accepted names in **bold face** and synonyms in *italics* together with the acronyms described above to lead the user to the designated alphabetical section: ***Abies*** P. Mill [ABIES$] Pinaceae (V:G), **Abies amabilis** (Dougl. ex Loud.) Dougl. ex Forbes [ABIEAMA] Pinaceae (V:G), *Abies excelsior* Franco = Abies grandis [ABIEGRA] Pinaceae (V:G). Again, introduced taxa are preceded by an asterisk*.

The Alphabetical List of Common Names like the Alphabetical List of Plant names has no page numbers but leads the user to the Systematic List via the accepted scientific name: **abbreviated bluegrass** = *Poa abbreviata* ssp. *Pattersonii* (V:M), **abraded brown** = *Melanelia fuliginosa* (L), **abraded brown** = *Melanelia subaurifera* (L).

The preface of this book should be read carefully by the user to ascertain the various aspects which are described above. In general, the nomenclature follows Kartesz (1994) for vascular plants, Anderson (1990) and Anderson et al. (1990) for mosses, Stotler and Crandall-Stotler (1977) for hepatics, and Esslinger and Egan (1995) for lichens. The authors reviewed many publications in the process of compiling this work which includes 4349 species and 604 infraspecific taxa. It is the largest number for a Canadian province. I can, however, add one more species. This is *Elymus sibiricus* L. Siberian Wild Rye (W. J. Cody, *Canadian Field-Naturalist* 81: 275. 1967) which is restricted in the province to the extreme northeast.

This volume has taken a tremendous amount of effort to complete and the authors should be congratulated for their concentration.

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Flora of Maine: A Manual for Identification of Native and Naturalized Vascular Plants of Maine

By Arthur Haines and Thomas F. Vining. 1998. V.F. Thomas Co., P.O. Box 281, Bar Harbor, Maine, 04069-0281. 848 pp., soft, U.S. $45.00 + $6.00 shipping.

A flora covering a single state, province, or territory is always a most welcome and useful tool for individuals interested in the flowering plants of that area as well as adjacent regions. The northern part of Maine is partly encircled by the provinces of Quebec and New Brunswick, while the southern part is bounded by the state of New Hampshire and the Atlantic Ocean. This state which measures 33 040 square miles (ca. 85 594 sq. km.) has a varied terrain from the height of Mount Katahin (5385 ft. = ca. 1641 m) to the salty shores of the Atlantic Ocean.

In this flora a total of 139 families, 699 genera and 2096 species, of which 39 have been added on the basis of the existence of a voucher specimen, plus numerous varieties and subspecies, have been treated.

The introductory pages of this volume include a preface in which 22 experts in various families and genera have contributed a significant amount to the text, plus 9 individuals, 3 herbaria and one corporation. This is followed by a brief History of the Flora of Maine. In the Introduction there are comments on the purpose, scope, taxonomy and nomenclature, keys, voucher specimens, and species descriptions. Two pages are devoted to lists of 39 additions and 58 exclusions since the publication of the third revision of the *Checklist of the Vascular Plants of Maine* (Campbell et al. 1995), and this is followed by a 20-page glossary.

"Families are arranged in phlylogenetic order, such that all monophyletic families are kept together, as far as is known (Angiosperm Phylogeny Group in prep. Bremer *et al.* 1998, Källeisjö *et al.* 1998, and references therein). Genera within families and species within genera are alphabetical. Finally circumscription follows Judd *et al.* (in prep.), who used monophyly as their primary criterion. Nomenclature is that of authors of Flora of North America, when available. Otherwise, primarily Kartesz (1994) was followed". For those who have been familiar with the order of families in Fernald (1950) in *Gray's Manual of Botany, Eighth Edition* or Gleason and Cronquist (1991) *Manual of Vascular Plants of Northeastern United States and Adjacent Canada, Second Edition* or such alphabetical treatments of families as Douglas et al. (1989, 1990, 1991, 1994) in *The Vascular Plants of British Columbia* this work may be difficult to follow, at least in the beginning because the families are in an order which had not yet been published when this volume went to press.

In the main text there is a record of the number of genera and species in each family, and number of species in each genus with occasional comments on individual families and genera. There are no family, genus, or species descriptions, but the keys are occasionally more descriptive than in other floras. For each species the following headings are provided: synonym(s), common name(s), habitat, range (American states are abbreviated but Canadian provinces are spelled in full as are such regions as Eurasia), state frequency, habitat, and notes. These headings are occasionally left blank but the notes are frequently quite interesting.

Following the main text there is Appendix I, a single page devoted to "Literature Cited". This includes general references rather than specific references to problems in the Maine flora, which to some extent is a missed opportunity. For example, citing the paper by Reznicek and Ball (Taxon 28: 217–223) which indicates the status of two endemic sedges of Maine would have been useful, and some would have expected a reference to it. This is followed by Appendix II which is a "Key to the genera for use with vegetative, non-emergent, aquatic plant material". This is a most useful key. Edward G. Voss (1972) in Part 1 of his *Michigan Flora* had a somewhat similar key for strictly submersed or floating aquatic plants. An index to families, genera, species and common names, plus a few blank pages for Notes complete the work. The only illustration with this book is on the front cover. It is of the only species which is known in Maine from a single locality, *Salix arctophila*. This was certainly an excellent choice.

It is inevitable that a few errors or omissions may occur in a volume such as this. The following might be corrected in a subsequent volume: In the text, the common name which is applied to the above species is "Arctic Willow", a name which is better applied to another northern species, *Salix arctica*. Unfortunately also, the range is given as "Greenland, s. to ME, w. and n. to Northwest Territories", but it is also known from far northern Yukon Territory and northeastern Alaska (Hultén 1968; Argus 1973; Cody 1996). The Main endemics *Carex josselynii* and *C. elachycarpa* are included in the index and synonymy, but it is not clear what happened to the endemic *Juncus oronensis* Fern. (included in Fernald's manual in 1950, but see P. M. Catling. 1988. The status of *Juncus oronensis*. Canadian Journal of Botany 66: 1574–1582). There appear to be a few omissions such as *Spiranthes casei* reported for Maine by Gleason and Cronquist (1991). The rank and names accorded some taxa are not current and groups are uneven in this regard: *Platanthera orbiculata* var. *macrophylla* for example should be treated as a species (Reddoch and Reddoch 1993. The species pair *Platanthera orbiculata* and *P. macrophylla*, Orchidaceae: taxonomy, morphology, distributions, and habitats. Lindleyana 8(4): 171–187), although the correct name for *Carex lanuginosa* (*C. pellita*), published the following year (1994) is included. In the genus *Salix* there are three keys: Key to the species for use with carpellate reproductive material (with 7 groups), Key to the species for use with staminate reproductive material (with 5 groups) and Key to the species for use with mature, vegetative material (with 7 groups). The species keyed in each of these 19 groups are not the same and could be confusing. A single key which starts with 1a: flowering plants 1b: mature vegetative material would be much safer.

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Rare Native Plants of British Columbia

By George W. Douglas, Gerald B. Straley, and Del V. Meidinger. 1998. Crown Publications, Victoria, British Columbia. 926 pp., soft, coil bound, $39.95 + 7% GST.

This is absolutely the best treatment of rare vascular plants yet published that I have seen for any Canadian province or United States state!! A half page is devoted to each of over 600 of the 2300 native vascular plant taxa known to occur in the province of British Columbia. These taxa are treated in the alphabetical order of genus and species and each has a map of the known distribution in the province, an excellent line drawing, and information on synonomy, common name, habitat/range, Global/Provincial Range, Status (Blue or Red), and frequently some interesting notes. Red "includes any indigenous species or subspecies considered to be Extirpated, Endangered, or Threatened in British Columbia" and Blue "includes any indigenous species or subspecies considered to be Vulnerable in British Columbia".

An introduction which includes maps of the Biogeoclimatic and the five Geographic regions of British Columbia is provided following the Preface, Acknowledgements, Table of Contents, and information on the Format. The main text is followed by References, Appendix 1 "Ranks, site numbers, and general locations of rare vascular plant taxa in British Columbia", Appendix 2 "British Columbia forest regions and forest districts", Appendix 3 "Ecosections of British Columbia, Appendix 4 "Collecting rare plants for the Conservation Data Centre", Appendix 5 "Numbers of Red- and Blue-listed taxa by forest district", Appendix 6 "Forest district Red/Blue taxa lists", indexes to scientific and common names, and an Addenda with 16 taxa added after the list of rare plants was completed, plus 10 name changes and 5 recently excluded species.

A work such as this is never finished. New information continues to arise, but for the moment this is a tremendous accomplishment. Congratulations!!

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ENVIRONMENT

Working for Wildlife: The Beginning of Preservation in Canada, Second Edition

By Janet Foster. 1998. University of Toronto Press, Toronto. Second edition. xx + 297 pp., illus. $21.95 Can.

The University of Toronto Press has reprinted, verbatim, this fine book in paperback, 20 years after the initial publication (which was based on Janet Foster's doctoral thesis at York University). As Anne Innis Dagg reported in her superb review in *Canadian Field-Naturalist* 92: 411–412, it deals with the history of the conservation movement in Canada until 1922, when "the first phase of wildlife conservation was complete."

The reissue in paperback has 24 pages of new material. Janet Foster's new preface recognizes that "Questions of conservation that once seemed so clear and easily answered have now become many-sided and more complex. ... [S]teadily shifting powers ... make both protection and preservation much more difficult to attain. ... Banff has become so overdeveloped that some call it a national disgrace." Yet Foster is encouraged by evidence that many civil servants "share the same dedication, commitment, and enthusiasm as those earlier civil servants" whose story she told in the first edition.

Dr. Lorne Hammond of the Royal British Columbia Museum provides a four-page Foreword, a six-page Afterword and eight pages of bibliography (105 citations published since 1978, but 22 prior to the appearance of Foster's first edition). Hammond's brief overview, amongst other things, places Foster's work in the context of 20 years of Canadian aboriginal studies, touches on ethnobotany, mentions six Canadian historians who have since built connections to Foster's work, and mentions equivalent studies in Africa, Mexico, and Australia.

This paperback reprint is highly recommended to anyone who missed purchasing a copy in 1978. Few of those who already own the first edition will be enticed to purchase this reprint.

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The World's Water: Biennial Report on Freshwater Resources, 1998–1999

By P. H. Gleick. 1998. Island Press, Washington. 307 pp., illus. U.S.$29.95.

Without water, life as we know it could not exist. This is a well-known and accepted fact. Exploration of our planetary system often focuses on the search for water, the sign that life could, or could have, exist(ed). However, even at the end of this scientific millennium, what we do not know about water on earth far exceeds what we do know. We seem to take it for granted.

Canada is one of the few places on earth with an excess of fresh water. Even our population centres are beginning to suffer from the lack of usable water. Almost everywhere we look we can see new examples of water being rendered unavailable through mismanagement and overuse.

Globally, this situation is far worse. Large parts of Africa, Asia, and South America have over 50% of the population without access to safe drinking water supplies. These are also the areas where population growth and industrialization are the fastest and where future global warming is predicted to reduce water supplies even further. Predictions have been made that the regional wars of the near future will be fought over water supplies.

It is about time that we learn more about the freshwater supplies of the world. Gleick's book is an excellent starting point, a good source of up-to-date information as well as predictions of future problems and recommendations for approaches to resolving them. This is the first edition of what is planned as a biennial publication. It fulfills a very important need and is highly recommended both as general reading and as a reference text.

The book is organized into an Introduction (which should be read, even if the rest is shelved for future reference), seven chapters: Changing Water Paradigm, Water and Human Health, Dams, Conflict over Water, Climate Change, Laws and Institutions, and Sustainability. In addition there is a chapter on Water Briefs and 19 detailed tables of data. Most chapters have excellent reference lists and some have technical appendices of their own.

The introductory chapter presents some interesting facts which should bring concern to any reader and raise interest in the details of the following chapters. Some interesting water facts:

- Water demands are increasing at a significant rate, while water availability is decreasing.
- Over half the population of the world lacks basic sanitation and over 1 billion lack potable drinking water.
- Water-related diseases are increasing significantly.
- Agricultural irrigation is on the decline, largely due to competition from urban demands.
- Groundwater use is currently unsustainable in every continent except Antarctica.

Over the last century, on a global basis, our population has risen 4 times and water withdrawal has risen 6 times. Until recently the typical reaction to rising water demand has been through development of new supplies. It is predicted that within the next twenty-five years, over 70% of the available freshwater resources of the world will be in use. Engineered solutions are running up against constraints of the lack of new physical resources, economic limitations, and environmental opposition. Signs are that the new desire to be sustainable is starting to work. In spite of world averages and its own growing population, water demand in the United States has declined by 10% over the past 20 years. The book provides much room for hope as well as documenting concerns. Many excellent ideas and references for sustainable water use planning are presented. This book is well worth reading for anyone concerned over our future.

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Nature Wars

By Mark L. Winston. 1997. Harvard University Press, Cambridge. x+210 pp. $34.95.

An entomologist at Simon Fraser University with two previous books on bees, Winston tackles the major problems encompassed by "people vs. pests" as this book is subtitled. He usefully blends profiles of specific cases and individuals with general discussion. The profiles focus on infestations of gypsy moth (especially communications campaigns to educate a public suspicious about bacterial spraying), insistence on pest-free homes driving cheap but hazardous chemical use, urban management of weeds (ranging from lawns through coyotes to birds at airports), treatment of outbreaks with sterile males and pheromones, bees as vital pollinators but endangered natural species, and transgenic plants. More general material includes a history of pest control (the Pied Piper is not mentioned), the widespread failure for more enlightened approaches since Rachel Carson's *Silent Spring*, and the small impact of integrated pest management compared to continued and massive reliance on chemical treatments. Most valuably, Winston delineates how management of pests, rather than their eradication, is one facet of a needed new view of living more in tune with the rest of the planet. Piquant instances, such as woodpeckers making holes in the space shuttle *Discovery* on its launch pad, flavour the text.

This is a very informative and highly readable book whose direct style provides clear explanations of both scientiific and technical issues as well as social, economic, and political aspects. Specific topics are laudably set in the context of larger subjects such as evolutionary ecology and environmental politics. The evaluation of such controversies as biotechnology is well balanced. The reader can thus understand, for instance, the magnitude of our use of chemicals, the inevitability of evolved resistance in pests, and why insect introductions are so frequent in a world of increasingly global trade. Also clear are the crucial roles of a scientifically literate public and of responsible government and media. The book includes an index and references but, unfortunately, the text is not directly linked to the latter by any notation. Most important is the emphasis with which Winston presents our responses to pests as a key indicator of our views on the natural world and our place in it. He could have pointed out that developments beyond pest management, such as in aninal welfare, indicate the same direction. This volume should find a wide audience for everyone concerned with these broad and important issues. Rachel Carson would justifiably not be pleased with our continuing abuse of the environment, as Winston correctly concludes, but she would certainly welcome his book.

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Environmental Sustainability: Practical Global Implications

Edited by Fraser Smith. 1997. CRC Press LLC, Boca Raton. 287 pp., illus.

In discussions of environmental sustainability the developed world's view has dominated. These views have largely ignored the developing world's approach to the issue of environmental sustainability. Fraser Smith has edited a book with the aim to redress the imbalance. The idea for the book originated from the second biennial meeting of the International Society for Ecological Economics in Stockholm in 1992. The essays collected are primarily rooted in the Third World experience. The authors originate from Jordan, Costa Rica, Philippines, Namibia, Peru, India, Brazil, Malaysia, Bangladesh, and Mexico.

The essays are proceeded by a framework paper by F. Smith to prepare the reader for what follows. The following papers are split into two parts; (1) Philosophical perspectives: Third World and First World compared and (2) Practical steps toward sustainability. There is a strong emphasis throughout that (a) the First World is a minority and (b) the Third World thinks and works more at the community level. Some expression of dissatisfaction with the First World colonialism occurs in a few of the essays. The essays as a whole demonstrate a different approach to environmental sustainability and priorities in general.

The book is well organized and well worth a read. The reader is provided a very different outlook to global issues. An outlook which often has not been heard or given a great deal of attention.

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Field Guide to Ecosites of the Mid-Boreal Ecoregions of Saskatchewan

By J. D. Beckingham, D. G. Neilsen, and V. A. Futoransky. 1996. Canadian Forest Service Northwest Region Special Report 6. University of British Columbia Press, Vancouver. xvi + 440 pp., illus. $29.95.

Reading this publication is a timely reminder of how young a science ecosystem classification is and how quickly it has matured. Lost among the present discourse on millennium matters is any remembrance that around the same time it will be 100 years since C. Hart Merriam released his seminal work on Life Zones. From that point more than another half century was to pass before Rachel Carson and the rapid post-war expansion of extractive industries started to focus attention on environmental concerns and, through them, on the need for a sounder factual basis to managerial decisions.

As a start, though, it was necessary to understand the environment better. Ecosystem guides made an appearance and have proven their worth in presenting the results of data collection and analysis in easily used forms with keys and explanations for arriving at a final determination. Writers of the Mid-Boreal

Guide have been able to draw upon all those that have gone before, particularly on works covering similar regions in northern Alberta where elevation and climatic variations are insufficient to generate prominent zonation of species. By selecting what they consider the best features and expanding or improving on others, they have arrived at what might be considered a second generation guidebook. What is noticeable is a movement away from dependence on informed subjective judgements to a position where analytical statistical techniques have been brought to bear. This does not mean the user has to employ advanced knowledge, just that the facts presented in this guide have been derived in a consistent way based on statistical determination. In most cases it allows the user to face variability knowing what percentage of instances are likely to fit the facts given and what percentage may differ, by how much and in which direction.

What is impressive is how such a dense mass of information has been packaged into a truly pocket-sized guide of roughly 18 × 11 × 2 cm. Production is sturdy for a paperback and even if time and rigorous usage in difficult surroundings take their toll, then at this price a replacement is not out of the question. In one respect it is almost two books in that the section on soil classification is almost an independent unit, available for use or not according to need. That part is preceded by detailed explanation for use of the whole book, the main body of work being on ecosite, ecosite phase, and plant community classification supplemented with full but succinct information on characteristics described by word and diagram. Most but not all the indicator plants are shown in a recognition section, each with one photograph and one line drawing of good standard with only one or two exceptions; a selection of soil types is also shown. A final division covers management interpretations and forest mensuration data acquired for each ecosystem surveyed, together with appropriate appendices and glossary information. If there are production or typographical errors they are cryptic; the only obvious one seen cites a book co-authored by Dr. Irwin Brodo as long ago as 1877 which has probably surprised him greatly.

Obviously this is a purpose-driven book designed to be used by workers — those in the forestry industry mainly but environmental consultants and other resource industries too — and not one for casual reading, though no doubt curious-minded naturalists and environmental activists could find material of use. There were a few times when the thought arose that a specialist in information lay-out might have presented things a little differently but to have handled this much data effectively is a *tour de force* in itself. As the area treated in this particular guide covers a swath of Saskatchewan from the Boreal Transition north of the North Saskatchewan River more or less to the edge of the Canadian Shield there are probably more in the series to come, if not already released. If standardization of ecosystem classification across Canada comes about in the future it could well be that this book provides the pattern.

MALCOLM MARTIN

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Greening the Ivory Tower

By Sarah Hammond Creighton. 1998. MIT Press, Cambridge, Massachusetts. 337 pp. U.S.$25.

Greening the Ivory Tower is an account of a research project at Tufts University in Medford, Massachusetts. The objective was to evaluate the university's environmental status. Using a grant from the Environmental Protection Agency they researched all conceivable areas of pollution and waste. Before anyone thinks that universities are nice clean places, they should realize that this "industry" is a significant contributor to pollution. For example UCLA is the third largest energy user in Los Angeles and Tufts used 110 million gallons of water annually. The cost of deferred maintenance (which has health and environmental implications) at universities in the United States is estimated at $26 billion. These and other data given in the book are eye opening and prove that environmental management is essential for a modern campus.

This book is one of the most thorough I have read at examining environmental aspects. In addition to the traditional concerns like air and water quality, the author also covers subjects like motivation. She begins by describing the university system and how that affects the way changes are made. To make decisions leading to change you need a solid database. The author describes the data gathering method, including "soft" data like people's attitudes.

Data were gathered for every area considered to have the potential for an environmental impact. The list of areas considered include solid waste, energy, lighting, indoor air quality, water, hazardous materials, construction, purchasing, dining services, office supplies, and laboratories. Some of these were broken down into more detailed aspects. For example, the laboratory section includes laboratory facilities and chemical use, plus information on course design.

The collected data were analyzed to define the potential for environmental improvement. Where appropriate, the author and her team define potential courses of action to eliminate or reduce a defined problem. Their approach included evaluating the social structure and sensitivities that need to be accommodate if real lasting change is to be realized.

One interesting item in the appendices is a reprint of the Talloires Declaration. This was created by a group of 35 university presidents who formed the "University Leaders for a Sustainable Future." This fine document describes the roles and policies a university will adopt in their effort to support a sustainable future for our environmental. As of April 1999, there are 262 signatories of which 21 are Canadian.

Anyone who is thinking of developing an environmental management system will do well to read this book. It does have a university bias, but environmental problems are universal. It is easy to transpose the information to other facilities. It does have a U.S. bias, but again there is little trouble in incorporating other regulatory regimes. The book also has a nice logical flow pattern which readers could use in developing their own program.

This book, however, could use a thorough edit by a professional editor. There are some very curious sentence constructions. For example, "information can inform successful decisions", "recycling programs require oversight (meaning supervision?) by paid staff," and "saved $50000 in avoided (lower?) tipping fees." There are some odd uses of words. For example, "purchasing buyers" — why not just buyers? The contents page has an error. There were several times when I found myself re-reading something I had read earlier with similar words and similar structure. While some repetition is necessary, I believe it is overdone, especially at the beginning of the book. A good editor would be able to polish up these rough spots.

I was a little horrified when the author said she had recruited students to "audit" the university. Environmental auditing is a profession requiring training and experience. I insist a recognized environmental auditors association certifies the auditors I use. Also auditing has to be performed against a standard, and the author did not mention adopting or creating such a standard. As I read on my fears diminished because I realized that the author meant "collecting data" rather than the classical definition of "environmental auditing." Data collection is a fine job for students, especially if it is done in an organized framework.

These problems are minor and do not detract from the usefulness of the book. I have already recommended the book to two people, as I believe it will help them considerably. Neither of them is at university or in the U.S.A.

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In Earth's Company: Business, Environment and the Challenge of Sustainability

By Carl Frankel. 1998. New Society Publishers. Gabriola Island, British Columbia. 240 pages. $19.95.

This book is a refreshing overview for those of us who do not read many of the environmental magazines. Carl Frankel is an environment and industry watcher and the editor of a magazine dedicated to environmental issues within the realm of business. He tells us what is going on in the business world, looking at the facts as well as the trends and from here comes to a vision toward which we could be moving. That we could be moving in the direction of a vision and can be paying attention to the environment is big business these days, but business is still directed to the financial bottom line and top-down management is one paradigm. The goal of environmental response is achieved most easily when the people involved in the company have their desires and hopes heard in the corporate boardrooms, another paradigm completely. It is a tension which is recognized in many major boardrooms and considered in many others. Then there are the many smaller competitors who know no such vision or even tension at this time, whose considerations are so wrapped up in staying solvent that any deviation from the status quo would threaten their livelihood. Consumer response also plays a major role in what a company can market, often with industry answering the needs of the largest numbers and most conservative consumers.

Any company publicly dedicated to the environment as well as to producing their product shows a mixture of good and bad motives. But their customers will be involved in the inconsiderate wastage on the part of 20% of the world's population consuming 80% of the world's goods and the reality is a planet headed for self-destruction. The other 80% of the world population is hurrying to catch up using the same paradigm, or simply tries to survive while their population is growing, and will need a way to feed itself after the world reaches that 12 billion population figure where the earth's agriculture will no longer sustain us. In light of the above scenario, the vision which Frankel articulates and discusses is sustainability.

Classical manufacture is likened to a pipe, with raw materials coming in the front of the pipe, and products as well as waste coming out the end of the pipe. In a sustainable industrial system, there is no pipe. One manufacturer's unused material is considered to be raw material for another company's product. One used-up and discarded machine is the raw material for another product. If there is an used portion, there will be a need in another product line, and if one byproduct is toxic, the system can be changed so that product will not be produced. There are no neutral quantities in sustainability — not out of a smokestack nor an outflow pipe nor in a landfill. If a something is not used in the product, it is a poison in the system and we know that our system, our global system cannot endure poisoning.

It is evident from industry that the science of designing chemicals to fit is already well-developed. In pharmaceuticals, the design of the drug takes place on the computer screen before the experiments to produce it are done in the lab. This nano-technology, designing the molecules needed, then creating the product to extract them, began with IBM's design of their corporate logo using 35 xenon atoms attached to a larger molecule, and technological forecasters expect commercially viable nanotech applications to become common within the next quarter century.

Using terms like Total Quality Management, Frankel takes us through the realities, the ambiguities, and the possibilities of industry reacting to the needs of the 21st century. We are not given a greenwash here. Frankel knows the players on both sides and shows insight into the course of industry and ecology. Readers are invited to look at the trends in Canada, the U.S., and Europe especially with regard to the behaviour of multi-national corporations: sometimes trying to integrate, sometimes complying grudgingly, and sometimes ignoring their own backyards in order to satisfy shareholders. I began the book with hesitancy, started reading it with interest, and ended using its arguments when talking to friends, drawing from the ideas presented, coupled with my own experience and other reading. That is just what a good book should do.

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Dictionary of Natural Resource Management

By Julian Dunster and Katherine Dunster. 1996. UBC Press, Vancouver, B.C. xv + 363 pp., illus. Cloth $90.00; paper $39.95.

Confucius said, "If language is not correct, then what is said is not what is meant; if what is said is not what is meant, then what ought to be done remains undone." This is the reason for dictionaries — so we use a common language to ensure communications are understood correctly.

If I were to create a dictionary for natural resource management I would include terms from ecology, forestry, and perhaps some geological terms for description of landforms. The Dunsters have included all this and much more. Defined words range from technical and scientific to ideological and philosophical. Terms from a number of disciplines are included: agriculture (e.g., postemergence and pre-emergence treatments), botany (e.g., inflorescence, phreatophyte, phyllopodic), ecology (e.g., nurse log), forestry (e.g., jammer), geology (e.g., lapilli, nunatak), and wildlife management (e.g., neotropical migrant). Social and political aspects of resource management are also included (e.g., alternative dispute resolution, consumer surplus, core shamanism, Earth First!, and resourcism). There is a slight bias toward forestry terms, but all fields are well covered. Three appendices cover classification of organisms, the geological time scale, and various conversion factors.

Definitions convey the necessary detail for an entry. They range from simple, but adequate, explanations to discussions of the impacts of the concepts within the term (e.g., disturbance's influence on diversity is discussed under the former term). Canadian/British spelling is used but no pronunciations are provided. Line drawings illustrate terms where necessary.

Generally the definitions are noncontroversial and in agreement with accepted usage. I found few definitions I would challenge. The definition of "global warming" (page 150) relates solely to anthropogenic warming of the atmosphere without mentioning natural fluctuations in climate that have occurred in the past without human influence. "Holism" defined as "[t]he idea that a whole is more than the sum of its parts" (page 164) is confused with synergism. I thought the definition of kurtosis should have indicated how it is measured. Overall, these are insignificant quibbles.

Few terms are missed. It is odd the Deep Ecology movement is discussed but shallow ecology is not. Similarly, parametric statistics are defined while nonparametric statistics are not. Other undefined words I eventually happened upon (e.g., proleptic and sylleptic) are fairly ecsoteric, quite specialized, and not closely related to natural resource management.

One of the sources of confusion in biology and management of biological resources is inconsistency of definitions among individual studies. This comprehensive dictionary has the potential to help alleviate this problem. Unfortunately, the steep price will keep it off most people's bookshelf. If you find a copy of this book on a library shelf it is worth browsing through, enjoying the diversity of entries as well as using the dictionary as a reference work.

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MISCELLANEOUS

Charles Doolittle Walcott, Paleontologist

By E. L. Yochelson. 1998. The Kent State University Press, Kent, Ohio. xvi + 510 pp., illus. U.S. $49.

It is the sad nature of our species to remember the last great act of a person, regardless of the events (great and small), leading up to so high a peak. No matter what, we seem to always ask "so what have you done lately?" Charles Doolittle Walcott (1850-1927) is a case in point. Contemporary popular history reveres him as the discoverer of Burgess Shale fauna while he was director of the Smithsonian Institute in Washington. Much of the current fame is in no small part due to the widely read book by Stephen J. Gould, *A Wonderful Life* (1989, W. W. Norton, New York) where Gould explores the discovery of the fauna but also how Walcott pigeonholed many of the new taxa into existing higher groups. To Gould, the fauna is more of an experiment and illustrates his evolutionary philosophy of contingency. But there was more to Walcott (obviously) than just the Burgess Shale fauna and it is this recent biography by Yochelson that fills out the popular image of this highly energetic man.

Charles Doolittle Walcott, Paleontologist is an extremely in-depth examination of the development of Walcott. He was a continuous note taker throughout most of his life, more so when he realized that science was his hope and dream. Born in New York state, the Walcott family was surrounded by fossils. A near-by quarry instigated the budding scientist's curiosity. By collecting and trading with other collectors, and later with scientists, this self-taught individual would eventually find his footing within the scientific circles. His first step in the professional arena was with paleontologist James Hall of the State Museum of Natural History of New York. There he began not only his professional work with fossils, he also gained practical training in working the politics of museums and politics in general. His talents in this last regard would prove extremely beneficial to him in his rise as a scientist and later head of the U. S. Geological Survey.

Much of Walcott's research centered on the problems of the Cambrian period. His devotion throughout his life to the biological and geological problems associated with this time period would have granted him the title of "Captain Cambrian". Though he published many articles (mostly technical descriptions; little in the way of grand theorizing), he was with almost equal veracity a field man. First working in the eastern states, he would eventually cover much ground in the great basins of America, over the mountains, and to the west coast. Occasionally, he sauntered into central and eastern Canada [his brief honeymoon, "otherwise known as field work" (page 213), was to Toronto and Montreal, eventually geologizing with Redpath Museum's Sir William Dawson], following the Cambrian and all its notorious trilobites. This duality of research and fieldwork was born out of the need of much of the geological community to understand the geological and biological make-up of some of the oldest sediments on the continent.

This, however, was not enough for Walcott. If there is any lesson to be learned from his life, it is his ability and the eventual personal cost to health from what is today called multitasking. He would at any one time be involved with numerous local, regional, and national organizations — and not just as a member, but as president, vice president, or secretary. It is impossible to list briefly where, in a single moment, Walcott's web of activity stretched, but suffice it to say that while employed at the United States Geological Survey he had his robust fingers in the pies of, for example, the Carnegie Institute of Washington (especially in its formation), The Rochester Academy of Sciences, the Imperial Academy of St. Petersburg (as a foreign member), The American Philosophical Society, American Academy of Arts and Sciences, or the Biological Society of Washington. Even though some of these were simply honory memberships, when Walcott did have free time, the numerous committees he was on, (like the one assessing the entire scientific resources of the U.S. government) consumed the rest of his time. Credit must be given to Yochelson for tracking all of Walcott's endeavors even though these are sometimes lost on the reader.

Politics played an important role in Walcott's life. To be able to achieve as much as he did he must have made a good impression on the powers that be. This not only reflected his strong abilities in science, but also recognized that he was a good administrator. But part of Walcott's problem may have been that he was too good (more so on the latter) and couldn't decline an offer to head some group or other. "This man" Yochelson says "could no more decline an office offered than a knight of King Arthur's round table could spurn a maiden in distress" (page 340). The result of this over-taxing of mental and physical strength was Walcott's continual ill health.

Much of Walcott's life he wrote himself in his journals where it is detailed rather matter-of-factly, sometimes omitting honours or what we would define as major events. Yochelson's takes great care in maintaining this style of writing: Walcott attending this meeting one day, another meeting that day, which can get rather dry and one wonders the necessity of seemingly irrelevant information. Admittedly, the author tries to liven the routine by offering little explanatory pearls of geological wisdom. "Natural history specimens" Yochelson bemoans in one instance, "are not like paintings in that they are seldom unique, but they do have some similarities in being increasingly rare." The book would also have a little more flow if the occasional bad grammar were rectified before final print (for example page 42, second paragraph).

In the end, after 468 pages of text, the reader will find there is no end. Yochelson leads the reader right up to the point of Walcott leaving the directorship of the U. S. Geological Survey and taking the office of secretary of the Smithsonian Institution — a position the general science reader knows more about. This abrupt end is a little disheartening, even in spite of the few flaws mentioned above. It would have been very informative to follow through with this ode to detail, to see in a more explanatory manner Walcott's life and surroundings immediately before, and forever after the famed Burgess Shale discovery. This would, of course, make the volume much larger (and one must know when to draw the line) but it is a shame that this particular story is incomplete.

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Passionate Minds: The Inner World of Scientists

By L. Wolpert and A. Richards. 1997. Oxford University Press, New York. 240 pp., illus. U.S. $37.00.

The sequel to the successful, *A Passion for Science* (1988, Oxford University Press), Lewis Wolpert and Alison Richards again gather up their tape recorders to collect the thoughts of many of the leading scientists of the day. The interviews originated with a BBC radio production, and successfully illustrate that within the diversity of scientific specialties, all these investigators begin with, and almost pride themselves on, their childish curiosity.

Multiple fields of research are represented here; cell biology, palaeontology, physics, genetics, physical anthropology, chemistry, immunology, just to name a few. This may seem too diverse a field for the average reader to comprehend or have interest in, but this is not the case. Each section (there are 23 interviews) begins with a brief synopsis of each person's talents (many are Nobel recipients), accomplishments, and the significance of his/her research in lay person's terms. The first "voice" the reader hears from the scientists is usually how they got into science in the first place. Some, like developmental biologist Nicole le Douarin, who is noted for her leading work on cell migration in the early development of eggs, found that after teaching grade school science for six years, practicing science was more to her liking and went back to university. Others, like mathematician Sir James Lighthill, noted for his work on fluid mechanics and the behavior of liquids and gases, was naturally drawn to his subject and succeeded at school.

Many of the interviews allow the scientists an opportunity to tell their story of how they do their science and the environment they work in. Jim Lovelock of "Gaia" fame, secludes himself and family in a country setting. "We are hermits by nature" he says about securing his time and privacy. Not associated with any institution for finances, the question is asked "so then how do you actually live?". A contradictory anti-establishment figure is Harvard's evolutionary biologist Richard Lewontin. His "radical" thoughts on how science is performed are contrary to his current employment at one of the preeminent conventional institutions. "I have to make a living like everyone else" he says, but having legitimacy in an institution like Harvard also provides a secure platform to speak from. Many others, however, are fully entrenched and happy with the academic or private sector surroundings.

Some of the interviewees provide direct answers in what makes a good scientist. Immunologist Avrion Mitchison believes that persistence is good but "it's also very important to know when to stop doing something" when all things fail. The social, political, and gender roles are discussed at much length (only two of the 23 interviews are women). Is competition good within science? How were your ideas received by your peers? Or as in the case of chemist Carl Djerassi, are awards beneficial to scientists? He replies by paraphrasing an unknown author saying that "The Nobel prize is very good for science, but terrible for scientists". Too many good people are left behind in the running.

Many of the scientists are obvious polymaths. James Lighthill, in answering the question "is there anything in the academic world that doesn't interest you", replies, "I've only really tried to study about sixty academic disciplines." Others, like Nobel prize winner Roald Hoffman, a theoretical chemist, crosses more culturally defined borders. His poetry "is an interesting way to understand the universe around us" (page 22).

All these scientists reveal unique, personal insight into the world of science revealing that it is not just a job, nine to five. It is a fun experiment of the mind, a 24-hour a day endeavor of trying to comprehend our world, and our selves. *Passionate Minds* is certainly a must read.

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NEW TITLES

Zoology

†A birder's guide to the Rio Grande Valley. 1999. By M. W. Lockwood, W. B. McKinney, J. N. Paton, and B. R. Zimmer. American Birding Association, Colorado Springs. vii + 280 pp., illus. U.S. $2 3.95.

†Blue ribbon Bow: a fly-fishing history of the Bow River, Canada's greatest trout stream. 1998. By J. McLennon. Johnson Gorman Publishers, Red Deer. 184 pp., illus. $22.95.

*Cheating monkeys and citizen bees: the nature of cooperation in animals and humans. 1999. By L. Dugatkin. Free Press (Canadian distributor Distican, Richmond Hill). 224 pp., illus. $37.

The classification of simple organisms and invertebrates. 1998. By Clearvue-EAV, Chicago. 3CD-ROMs. U.S. $225.

*Habitat characteristics of some passerine birds in western North American taiga. 1999. By B. Kessel. University Alaska Press, Fairbanks. x + 117 pp., illus. U.S. $16.95.

†The history of British mammals. 1999. By D. Yalden. Poyser (Harcourt Brace, Sidcup, U.K.) 305 pp., illus. $29.95.

†New world blackbirds, the icterids. 1999. By A. Jaramillo and P. Burke. Princeton University Press, Princeton, 431 pp., illus. U.S. $49.50.

*The platypus and the mermaid and other figments of the classifying imagination. 1997. By H. Ritvo. Harvard University Press, Cambridge. xiv + 288 pp., illus. U.S. $15.95.

Rattlesnake: portrait of a predator. 1998. By M. Rubio. Smithsonian Institute Press, Washington. xxxi + 240 pp., illus. U.S. $39.95.

Rocking the boat: conserving fisheries and protecting jobs. 1998. By A. B. McGinn. Worldwatch Institute, Washington. 92 pp., illus. U.S. $5.

Trogons, laughing falcons, and other neotropical birds. 1999. By A. F. Skutch. Texas A & M University Press, College Station. 232 pp., illus. U.S. $29.95

Botany

Desert wildflowers of North America. 1998. By R. J. Taylor. Mountain Press, Missoula. x + 348 pp., illus. U.S. $24.

*Gleason's plants of Michigan: a field guide. 1998. Revised by R. K. Rabeler. Oak Leaf Press, Ann Arbour, Michigan. 398 pp., illus. U.S. $21.95.

Inside the Dzanga-Sangha rain forest. 1998. Edited by F. Lyman. Workman, New York. 128 pp., illus. U.S. $12.95.

Mushrooms. 1998. By T. Laessoe and G. Lincoff. D. K. Publishing, New York. 304 pp., illus. Cloth U.S. $29.95; paper U.S. $17.95.

*Shinners and Mahler's illustrated flora of north central Texas. 1999. By G. M. Diggs, Jr., B. L. Lipscomb, and R. J. O'Kennon. Austin College Centre for Environmental Studies and the Botanical Research Institute of Texas, Austin. 1626 pp., illus. U.S. $91.55.

Environment

*The book of nature: natural history in the United States, 1825-1875. 1998. By M. Welch. Northeastern University Press, Boston. xiv + 289 pp., illus. U.S. $50.

Empire's nature: Mark Catesby's new world vision. 1999. Edited by A. R. W. Meyers and M. B. Pritchard. University of North Carolina Press, Chapel Hill. 296 pp., illus. Cloth U.S. $60; paper U.S. $24.95.

Life out of bounds: bioinvasion in a borderless world. 1998. By C. Bright. Norton, New York. 287 pp., illus. U.S. $13.

The natural wealth of nations: harnessing the market for the environment. 1998. By D. M. Roodman. Norton, New York. 304 pp., illus. U.S. $13.

Land resources: how and for the future. 1998. Cambridge University Press, New York. xii + 319 pp., illus. U.S. $74.95.

Nature and culture in the Andes. 1999. By D. W. Gade University of Wisconsin Press, Madison. 312 pp., illus. Cloth U.S. $45; paper U.S. $18.95.

†Nature's geography: new lessons for conservation in developing countries. 1998. Edited by K. S. Zimmerer and K. R. Young. University of Wisconsin Press, Madison. xvi + 351 pp., illus. Cloth U.S. $60; paper U.S. $29.95.

A primer for environmental literacy. 1998. By F. B. A. Golley. Yale University Press, New Haven. xiv + 254 pp., illus. Cloth U.S. $37.50; paper U.S. $18.

*The world's water: the biennial report on freshwater resources. 1998. By P. H. Gleick. Island Press, Washington. 307 pp., illus. U.S. $29.95.

Miscellaneous

By the light of the glow-worm lamp: three centuries of reflections on nature. 1998. Edited by A. Manguel. Plenum Press, New York. ix + 373 pp. Cloth U.S. $32.50; paper U.S. $19.95.

†Memorabilia of the Entomological Society on Ontario and its London branch (1864–1881) while headquartered in London, Ontario from 1872–1906. 1999. By W. W. Judd. Phelps Publishing, London, 74 pp., $10.

Shield country: the life and times of the oldest piece of the planet. 1999. By J. Bastedo. Red Deer Press, Red Deer. 276 pp., illus. $22.95.

Books for Young Naturalists

Birds; Flowers; Mammals; and Trees. 1998. By E. Glesecke. Heinemann Library, Des Plaines, Illinois. Each 24 pp., illus. U.S. $13.95.

Bobcat; Cougar; Feral cat; and Lynx. 1999. Blackbirch Press, Woodbridge, Coonecticut. Each 24 pp., illus. U.S. $14.95.

Chirping crickets. 1998. By M. Berger. Harper Collins Children's, New York. 32 pp., illus. Cloth U.S. $15.95; paper U.S. $4.95.

Deer, moose, elk, and caribou. 1998. By D. Hodge. Kids Can Press, Buffalo. 32 pp., illus. U.S. $10.95.

Desert life; Pond life; and Rain forest. 1998. By B. Taylor. Covent Garden/DK, New York. Each 32 pp., illus. U.S. $4.95.

Forests for the future. 1998. By E. Parker. Raintree Steck-Vaughn, Austin. 48 pp., illus. U.S. $25.68.

A home by the sea: protecting coastal wildlife. 1998. By K. Mallory. Gulliver Green, San Diego. 64 pp., illus. Cloth U.S. $18; paper U.S. $9.

How caterpillars turn into butterflies. 1999. By J. Bailey. Marshall Cavendish, Tarrytown, New York. 32 pp., illus. U.S. $15.95.

How insects work together. 1999. By J. Bailey. Marshall Cavendish, Tarrytown, New York. 32 pp., illus. U.S. $15.95.

How the wolf became the dog. 1998. By J. Zeaman. Watts, Danbury, Connecticut. 64 pp., illus. Cloth U.S. $24; paper U.S. $8.95.

They swim the seas: the mystery of animal migration. 1998. By Simon Browndeer Press, San Diego. 40 pp., illus. U.S. $16.

Tide pool. 1998. By C. Gunzi. Covent Garden/DK, New York. 32 pp., illus. U.S. $4.95.

*Assigned for review
†Available for review

Index to Volume 113

Compiled by Leslie Durocher

Index to Book Reviews

TABLE OF CONTENTS *(concluded)*

News and Comment

Book Reviews

Mailing date of the previous issue 113(3) : 14 September 1999

Articles

Notes

(continued on inside back cover)

ISSN 0008-3550