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February 1998
at SASKATOON, SASKATCHEWAN

Edited by:

Jeffrey Thorpe
Taylor A. Steeves
Mike Gollop

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RE-GROWING THE LAND **RE-GROWING OURSELVES**

1998 Prairie Conservation and Endangered Species Conference

February 19 - 22, 1998

Saskatoon Inn
Saskatoon, SK

THE FIFTH PRAIRIE CONSERVATION AND ENDANGERED SPECIES CONFERENCE WAS PRESENTED WITH SUPPORT FROM:

- Canadian Wildlife Service
- World Wildlife Fund
- Alberta Agriculture, Food and Rural Development
- Provincial Museum of Alberta
- Saskatchewan Agriculture and Food
- Uranerz Exploration and Mining Limited
- Alberta Environmental Protection
- Canadian Wildlife Federation
- Canadian Cattleman's Association
- Grasslands National Park
- Manitoba Natural Resources
- Riding Mountain National Park
- Saskatchewan Environment and Resource Management
- SaskEnergy
- Ducks Unlimited Canada
- Golder Associates
- Meewasin Valley Authority
- Saskatchewan Research Council
- TransCanada Pipeline
- Nature Conservancy of Canada
- Canadian Association of Petroleum Producers
- Stanley Consulting Group Ltd.

DISPLAYS AT THE CONFERENCE INCLUDED:

- Gail Adams, Wildlife Artist
- Canadian Land Reclamation Association
- Canadian Parks and Wilderness Society Saskatchewan
- Ducks Unlimited Canada, flushing bars and other DUC programs
- Ducks Unlimited Canada, Thunder Creek DUC Project
- Bud Ewancha, Preservation of Gull Lake, Manitoba, Wetlands
- Grazing and Pasture Technology Program
- Lethbridge Community College
- Manitoba Roundtable
- Meewasin Valley Authority
- Mixedgrass Prairie Habitat Restoration Project
- Nature Saskatchewan, Bat Display
- Nature Saskatchewan, Burrowing Owl Conservation and Education In SK
- Prairie Farm Rehabilitation Administration
- Purple Loosestrife Eradication Project
- Saskatchewan Wetlands Conservation Corporation
- Saskatchewan Environmental Society
- Saskatchewan Outdoor Skills Training and Awareness Program
- University of Saskatchewan Extension

CONFERENCE RESOLUTIONS:

During the course of the conference, eight resolutions were proposed. Conference participants were invited to submit a ballot voting either for or against each resolution. All eight resolutions received high endorsement by voting participants. A total of 105 completed ballots were received by the end of the conference. The resolutions and ballot results are as follows.

Resolution Number 1 (Yes - 84; No - 6)

BE IT RESOLVED that this conference acknowledge that any further quantitative expansion in the human economy is at the expense of the economies of other species and that this, above all else, is the cause of the decline in biodiversity.

Resolution Number 2 (Yes - 77; No - 13)

BE IT RESOLVED that the steering committee of this conference designate a group to work, in consultation with the various native prairie stakeholders, towards establishing a "Native Prairie Appreciation Week".

Resolution Number 3 (Yes - 84; No - 8)

BE IT RESOLVED that the next PCAES Conference: 1) examine issues related to conservation education; 2) present an award that recognizes excellence in conservation education; and, 3) as an award, make a donation to a cause chosen by the award recipient.

Resolution Number 4 (Yes - 81; No - 10)

BE IT RESOLVED that we insist that industry and government research and inform the public about the effects of pesticides on non-target species — wildlife, people, beneficial species — and increase the stringency of guidelines for allowable pesticides in drinking water.

Resolution Number 5 (Yes - 82; No - 5)

WHEREAS the people of Saskatchewan desire fair and equitable taxation, and
WHEREAS the recent change in taxation places a greater tax burden on ranchers grazing cattle on large holdings of land in southern Saskatchewan grasslands, and
WHEREAS this tax burden may lead to increased pressure (grazing, cultivation) of such grasslands, and
WHEREAS grasslands provide numerous important ecological services for Saskatchewan people (e.g., maintaining a natural water cycle, minimizing soil erosion, contributing to CO_2 reduction, and sustaining many rare and endangered species),
THEREFORE, BE IT RESOLVED that the participants of the 5th PCAES conference mandate that:
1) a committee be struck to examine recent changes in taxation and their impact on grassland conservation; and,
2) that this committee broadly represent different disciplines and stakeholders; and,
3) that the committee review approaches that are consistent with fair and equitable taxation, stewardship and conservation, and ecosystem protection;and,

4) that the committee produce a document which reports on the review and makes recommendations for action.

Resolution Number 6 (Yes - 85; No - 7)

WHEREAS, the people of Canada respect the use of private property and private enterprise, within the limits set by society to achieve a quality of life; and,
WHEREAS, some lands in prairie Canada are so sensitive ecologically as to be threatened by wind and water erosion; and,
WHEREAS, not all currently practiced land uses are consistent with conservation of this sensitive land's life support system; and,
WHEREAS, some of the most important remnants of Canada's once spectacular grasslands are in public ownership; and,
WHEREAS, individual private landowners can not be expected to protect land merely for the ecological services it provides for all Canadians and the Biosphere,
THEREFORE, BE IT RESOLVED that the participants of the 5th PCAES urge:
1) that existing public lands continue to remain in public ownership; and,
2) that these lands may be managed under a "multiple use" framework with priority given to ecosystem conservation; and,
3) that any future review of this approach be done with input broadly selected from within Canadian society.

Resolution Number 7 (Yes - 83; No - 4)

WHEREAS, the government of Saskatchewan recognizes the value of wildlife habitat; and,
WHEREAS, the government has policies and programs to encourage wildlife habitat conservation; and,
WHEREAS, the government maintains policies and legislation, such as the "Farmland Security Act", that impede the activities of habitat conservation organizations,
THEREFORE, BE IT RESOLVED that the government of Saskatchewan amend the "Farmland Security Act" to remove encumbrances that restrict conservation and organizations and agencies from protecting wildlife habitat and natural heritage sites through land purchase and conservation easements.

Resolution Number 8 (Yes - 73, No - 2)

WHEREAS, in Alberta, compensation for effects of industrial activities on public rangelands is negotiated directly between industry and the grazing leaseholder; and,
WHEREAS, only a small portion of the compensation funds go directly to provincial revenues; and,
WHEREAS, this policy inflates the value of public lease transfers and creates rewards for leaseholders for industrial development on native range; and,
WHEREAS, it also results in a reluctance of grazing leaseholders to commit to habitat protection on public lands,
THEREFORE, BE IT RESOLVED that this policy needs to be re-examined in light of the goals of prairie conservation and the need to provide fair and equitable compensation for loss of grazing opportunity.

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LIVING IN, ON AND ABOVE THE LAND

OPENING SESSION

DESIGNING THE 5TH PRAIRIE CONSERVATION AND ENDANGERED SPECIES CONFERENCE

Josef K. Schmutz

Department of Biology, 112 Science Place, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5E2

I'm proud to have been working with 17 collaborators in the design of what is now the Fifth Prairie Conservation and Endangered Species conference. When our steering committee first considered what our focus should be for the Saskatoon conference, we looked at past themes for guidance (Figure 1). It appeared to us that, among all the worthy themes in the past, perhaps the biosphere and Canadian/global community dimensions had not been fully explored. This is not to say that these dimensions were not implicit in the topics addressed previously, but we tried to find ways to make these dimensions explicit. We decided on the theme "Integrating Conservation, Society, Ethics and the Economy."

Any endeavor will do well to be aware of its roots - the forces that drive it. Conferences are "driven" by participants or by single special interest sponsors, of which in this case there were none. As chairperson of the program subcommittee, I was both conscious of and anxious about the risk of moving too far from an audience's expectation. The Prairie Conservation and Endangered Species Conferences have cultivated a dedicated audience over the years. What would attract and inspire this audience this time? In an attempt to hold on to the conference tradition and at the same time move further afield, we decided to structure the first day with three important elements. First, we wanted to cover the usual topics of the status of habitats and the endangered species within them. Second, we wanted to give the audience ample choice, which we achieved with concurrent sessions. Finally, we wanted to encourage informal meetings and discussion. Past PCAES conferences were called workshops because audience participation was sought. We hoped that an excellent poster program, with ample time specifically set aside in the program and with authors present, would facilitate people meeting kindred conservationists and encourage exchange of ideas. The other one one and one-half days were structured to integrate explicitly. This integration, we hoped,

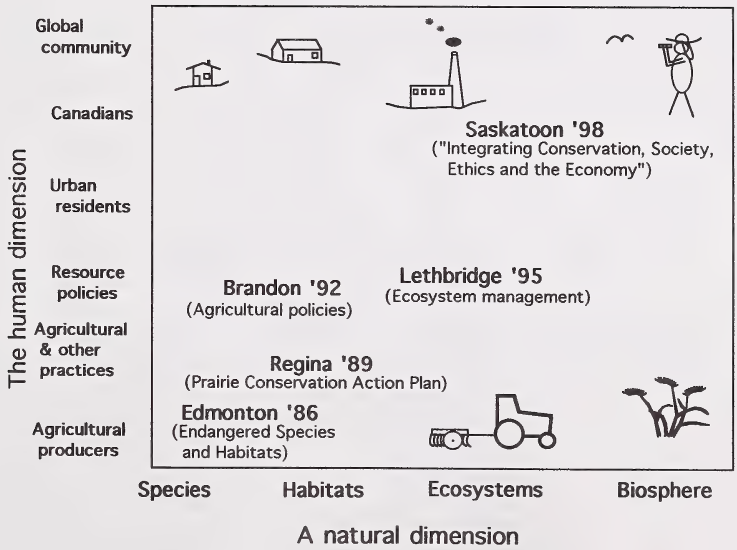

Figure 1. An attempt is made here to place previous and current PCAES themes on two axes. One axis is meant to portray a gradient of human enterprise from individual action to the global community. A second axis represents the natural dimension at different scales.

would emerge through the participation of presenters who would provide a synopsis of their sub discipline. Having several of these back-to-back and dealing with one "supertopic" at a time (agriculture, policies and law, ethics), would allow the audience to integrate ideas. Integration would then be further encouraged by having carefully chosen speakers reveal the underlying assumptions in one or more paradigms. In addition, the art show perhaps allowed us to look for complementarity between our inner passion and outer activities.

As part of integrating conservation with society, ethics and the economy, it presumably is important to recognize what motivates people to conserve. A "subset question" within the previous bigger question might be: Why do people come to this conference? Participants might come because i) they share a passion for the natural world, ii) because they share a sense of crisis that our life support system is disintegrating before our eyes (and it may come back to haunts us), or, iii) finally, because we have a professional interest (a park naturalist or rancher) and this relates to our making a living. I imagine that in most cases motivation stems from some of each.

Anyone interested in furthering conservation action on the part of a society, local or global community, would do well to examine the determinants and barriers to action. Conservation action, or inaction, is perhaps as naturally founded within us as the subconscious nervous system and muscular system maneuvers involved in catching a ball in flight. Academics naturally place great value on "knowledge," mostly scientific knowledge. This has sometimes gone so far that the public is treated as a "blank slate" expected to receive and act on scientific advice largely unquestioned (Weeks and Packard 1997). An overconfidence in the importance of scientific knowledge also often leads to an inflation of the promised benefits, as in grant proposals (e.g., Langenberg 1991). Many non-academics have accepted the supposed power of a singular science, but there are also signs that trust is eroding. Actually, wisdom may be something that includes traditional knowledge, local knowledge, science, insight and ethics. More often than not, the best action is that which integrates as many of these dimensions as possible, across the economic, natural and social realms. A legal instrument that is not supported by sufficient social will is likely to cause more alienation than good. When to poison ground squirrels or mosquitoes is a decision that has perhaps far more roots in the ethical realm than in the scientific. How is one to rank scientific knowledge with local knowledge? Local knowledge is very powerful for rare events and long-term trends. For example, the French Academy of Sciences refused to accept the existence of meteorites for nearly a century because they were never witnessed by academy members (Barnes 1988). There are many barriers to genuine conservation and among these are disciplinary, sectoral or social chauvinism. Perhaps we can ask ourselves at this conference: What would these barriers look like if we saw them?

One prerequisite for conservation action is that people with diverse interests understand one another. One frequently hears the judgment that a particular view is right or not right. Perhaps the more interesting question about a discordant view is to ask: What assumptions, experiences or ways of knowing would I have to accept in order to share this view? Different people reject or accept different assumptions for a variety of reasons. Merchant (1992) has identified some major World views on how humans relate to ecology:

The principles of deep ecology entail "...a new psychology, or new philosophy of self,...of humans in nature, not above it... This means a total intermingling of person with planet... reinhabiting the land as 'dwellers in it.' [Deep ecology] rejects industrial society as the world paradigm for development and entails leaving vast tracts of land as wilderness... For each ecological region, the guideline for use should be human carrying capacity... In using nonhuman nature, people have a duty to maintain the integrity of the ecosphere, not to conquer it or make it more efficient. Although living entails some killing, other organisms have a right to exist and evolve just as do humans... a new ecologically-based science promotes a sense of human place within the household of nature... Biological and cultural diversity are desired ends" (Merchant 1992:86-88).

"Spiritual ecology, like deep ecology, is a product of a profound sense of crisis in the ways that twentieth century humans relate to the environment. Like deep ecology it focuses on the transformation of consciousness, especially religious and spiritual consciousness... Religious ideas create strong moods and motivation that act as an ecocentric ethic, guiding individuals and social movements towards new modes of behavior" (Merchant 1992:111-112)

Social ecology: "Industrial development has brought neither social justice nor a healthy environment to all people. Both the progressive and environmental [social ecology] movements look beyond the individual to the social and environmental whole for values by which to restructure the world.... People working together can create opportunities to keep their own environments clean and remove neighborhood poverty. But a world in which there is room for both humans and wildlife cannot be achieved by biological methods or social programs alone. Expanding meaningful opportunities for employment, especially for women, food and housing subsidies, and appropriate technologies that can be repaired at the local level are methods that can help to lower population growth rates. Ecologically sensitive agriculture that helps to reduce pesticide residues and water salinization could improve social conditions" (Merchant 1992:133-134)

Green Politics: "The environmental movement in the 1990s has arrived at a crossroads. At the intersection, several branches take off in different directions. The avenue on the right is newly paved and its center strip is painted white. Down this highway travel large numbers of established environmental groups, carrying banners that read 'Wilderness forever,' 'Save the birds.' 'Clean up the oilspill.' Known as the Group of Ten, the ranks of these organizations have swelled markedly in response to the Reagan 'anti-environmental' decade of the 1980s." The Group of Ten includes: Environmental Defense Fund, Environmental Policy Institute, Friends of the Earth, Izaak Walton League of America, National Audubon Society, National Parks and Conservation Association, National Wildlife Federation, Natural Resource Defense Council, Sierra Club, Wilderness Society.

"At the intersection, a branch toward the left is under new construction. Still rocky and covered with multicolored soil, the construction work is being carried out by grassroots activists. Concerned that the road pass through clean air and waters and that its workforce be treated fairly, the builders stop frequently to oppose dumpsites, pollutants, and the victimization of peoples of color. At a bend, an obscure trail turns off to the left. Down it move those bent on civil disobedience in defense of nature - Earth First!ers and animal liberationists."

"At the center of the crossroads, a new road is still in the planning stage. Here people dressed in green clothing are preparing for construction by painting signs reading 'We are neither left nor right, we are in the front'."

"Green politics groups act to change the ways in which both capitalist and socialist production are reproduced through laws and governance" (Merchant 1992:157-158).

Ecofeminism "In Kenya, women of the Green Belt movement band together to plant millions of trees in arid degraded lands. In India, they join the chipko (tree-hugging) movement to preserve precious fuel resources for their communities. In Sweden, feminists prepare jam from berries sprayed with herbicides and offer a taste to members of parliament: they refuse. In Canada, they take to the streets to obtain signatures opposing Uranium processing near their towns. In the United States...social and socialist ecofeminism ground their analyses in capitalist patriarchy. They ask how patriarchal relations of reproduction reveal the domination of women by men, and how capitalist relations of production reveal the domination of nature by men. The domination of women and nature inherent in the market economy's use of both as resources would be totally restructured. Although cultural ecofeminism has delved more deeply into the women-nature connection, social and socialist ecofeminism have the potential for a more thorough critique of domination and for a liberating social justice."

"An ecofeminist ethic is both a critique of male domination of both women and nature and an attempt to frame an ethic free of male-gender bias about women and nature" (Merchant 1992:183-184).

Sustainable development: "Sustainable agriculture is part of a larger program of sustainable development oriented to converting ecologically destructive production into environmentally sound production. Unlike green politics and ecofeminism, which act to resolve the contradiction between production and reproduction, the sustainability movement attempts to resolve the contradiction between production and ecology by making production ecologically sustainable. Like the green and ecofeminist movements, however, the sustainable development movement is diverse, containing within it a spectrum of political approaches and ethical orientations" (Merchant 1992:212).

"'Humanity has the ability to make development sustainable,' declared the Bruntland report, 'to ensure that it meets the needs of the present without compromising the ability of future generations to meet their needs'...While the Bruntland report has received much praise for its comprehensive examination of global environmental problems, its emphasis on a growth oriented industrial model of development has been criticized by some developing countries" (Merchant 1992:228-229).

In a World as complicated as ours is today, it might no longer be meaningful to say if group X would only practice Y instead of Z, all would be well. Because of enormously complicated modern societies, it is often difficult to foresee undesirable consequences of a seemingly innocent or even well intentioned act (Saul 1995). Buffy Sainte-Marie relayed a story to the audience at one of her concerts. She sat in an airplane, next to a young soldier who was on his way to a potentially life-threatening deployment. She was distraught at this and began to ask how it was that we have soldiers and wars. She relates this questioning in the lyrics below, entitled "The universal soldier" (Sainte-Marie no date). This song could be adapted and called "The universal environmentalist." Both the soldier and the environmentalist generally confront a wrong directly, when in reality the causes of war and "resource injustices" often have their (indirect) root causes very far removed.

He's five foot two and he's six feet four
He fights with missiles and with spears
He's all of 31 and only 17
He's been a soldier for a thousand years

He's Catholic, a Hindu, an Atheist, a Jain
A Buddhist and a Baptist and a Jew
And he knows he shouldn't kill
and he knows he always will
Kill you for me my friend and me for you

He's fighting for Canada
He's fighting for France
He's fighting for the USA
And he's fighting for the Russians
And he's fighting for Japan,
And he thinks he will put an end to war this way.

And he's fighting for democracy
And fighting for the Reds
He says it's for the peace of all
He's the one who must decide
who's to live and who's to die
And he never sees the writing on the walls.

But without him how would Hitler have
condemned him at Dachau
Without him Caesar would have stood alone
He's the one who gives his body
as a weapon to a war
And without him all this killing can't go on.

He's the universal soldier and he
really is to blame
His orders come from far away no more
They come from him, and you, and me
and brothers can't you see
This is not the way to put an end to war.

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KEYNOTE LECTURE: FROM BIOLOGICAL DIVERSITY TO ECOSYSTEM MANAGEMENT

Fritz L. Knopf

U.S. Department of Interior, Fort Collins, Colorado

Abstract: The historical landscapes of the Great Plains have been altered substantially over the last 100 years. Conserving the biological diversity of the Great Plains requires protecting the biotic integrity of the region. Biotic integrity refers to those species that specifically evolved in the Great Plains. Thus, instead of needing to manage lands for all species that occur on the plains, conservation can focus on relatively few selected species. I make the points that biological diversity has nothing to do with the number of species present, cannot be defined from a local perspective, and is not served well by most wildlife conservation enhancements. Rather, biological diversity addresses issues of biotic integrity (endemic species), is defined from regional or higher perspectives, and is consistent with endangered species programming. The methodological approach to conserving biological diversity requires that conservation biologists 1) understand the differences between local and regional diversity as operational paradigms for decisions; 2) emphasize biotic integrity in conservation planning; 3) restore ecological processes that favor endemic species; and 4) promote ecological sustainability of biological resources through time. Historical perspectives are an oft overlooked, but highly critical component of diversity decisions.

Within a locale, the "variety of life" is often expressed as the number of different species present. Providing the maximum number of habitats for species is generally viewed as good wildlife management both within the profession and by the sponsoring public.

The native biota of North America evolved within many biogeographic regions. Species that evolved in a single biogeographic region are considered endemic to that region. Species with less specific requirements are ecological generalists. Generalist species cross biogeographic provinces and are more cosmopolitan in their distribution.

Management of wildlife habitats is generally at the local scale (wetland, grazing allotment, timber sale, etc.). Compounded across larger areas, the integrity of entire biogeographic regions as tallgrass prairie or ponderosa pine (*Pinus ponderosa*) forest becomes fragmented (Harris 1984). Fragmentation favors range expansions of ecological generalists (Knopf 1986, Soulé 1990) and progressively restricts the habitats for endemic species (Robbins et al. 1989). The number of generalist species moving into an area always exceeds the number of endemics lost, and interspecific relationships among resident species change with faunal composition (Brittingham and Temple 1983, Wilcove 1988*a*). Thus, most contemporary faunas have more species now than historically, yet lack the biotic integrity of the biogeographic region. It is not surprising, then, that endangered species as Hawaiian birds, the California condor (*Gymnogyps californianus*), mountain plover (*Charadrius montanus*) and black-footed ferret (*Mustela nigripes*) are those that generally (1) are endemic to a biogeographic province; (2) represent the biotic integrity of that province; and (3) contribute the most to biological diversity at the continental scale. The goal of conservation biology is to minimize local while maximizing regional species diversity (Temple et al. 1988, Wilcove 1988b).

Fragmented landscapes are the product of fragmented administrative lines laid over biogeographic provinces. A given biogeographic province may have several operational offices within a multitude of agencies, often nested across separate political states (for a specific example see Knopf and Scott 1990). Each office lacks the jurisdictional authority to speak to issues at the biogeographic scale. The Endangered Species Act and Wildlife Conservation Act of 1980 (known as the "Nongame Bill") both include specific language to pass funding to the individual states for management. Most states, in turn, comprise more than one biogeographic province, but rarely consider the status of a habitat or species in contiguous states which also lie within a given province. Such fragmentation of policy and operations favors management of species on the edges, rather than in centers, of their continental distribution. Conservation of native biodiversity necessitates planning inputs from regional and national perspectives

(Knopf 1992, Committee on the Environment & Natural Resources 1995). It is precisely this lack of higher level administrative coordination that precipitated congressional and private sector interest in the Biodiversity Bill (HR 585) that includes an interagency authority for biodiversity conservation.

Major decisions to conserve biological diversity are being made daily, often without the time to acquire the best scientific evidence (Knopf and Samson 1994a). Wildlife managers/conservation biologists must assure that actions to conserve biological diversity will not, in practice, be counterproductive (Murphy 1989). Conservation of the native biological diversity of North America demands that resource agencies (1) minimize practices that promote greater species richness at local sites, (2) emphasize between-habitat diversity at the management unit level, and (3) implement a top-down approach to prioritizing decisions about the conservation of biological diversity (Samson and Knopf 1982).

Because biological diversity can be defined across biological, spatial, and temporal scales (Knopf and Smith 1992), field biologists often express extreme frustration as to how to effect constructive conservation practices. Recently, Samson and Knopf (1993a) developed the following four guidances to assist in daily decisions regarding diversity issues: (1) understand alpha vs. beta diversity; (2) emphasize biotic integrity; (3) restore ecological processes; and (4) promote sustainability of biological resources. To date, land managers have emphasized species-rich sites (Knopf and Samson 1994*b*). Alternatively, we need to maintain or restore the range of natural ecological variation that supports the biotic integrity of native ecosystems (Samson and Knopf 1993b). Declining populations of endemic species are barometers of ecosystem dysfunction and it is these endemic species that ultimately become endangered of extinction. Thus, efforts that identify and protect endemic species are fundamental to managing the health of native ecosystems (Knopf and Samson 1997, Samson and Knopf 1996a,b).

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BIODIVERSITY ISSUES

THE BIODIVERSITY CRISIS IN SOUTHERN SASKATCHEWAN: A LANDSCAPE PERSPECTIVE

Paul C. James, Kevin M. Murphy, Fred Beek, and Randy Seguin

Fish and Wildlife Branch, Saskatchewan Environment and Resource Management, 3211 Albert Street, Regina, Saskatchewan S4P 5W6

Abstract: The current status of terrestrial biodiversity in southern Saskatchewan was assessed through the use of recent satellite vegetation cover maps and a Geographic Information System (GIS). 1:50,000 (n=126) map sheets were used to estimate the amount and configuration of native vegetation remaining with the Prairie Ecozone and within each of the Mixed Grassland, Moist Mixed Grassland and Parkland Ecoregions. A general species-area model predicted that very high levels of species' extirpation have already occurred across the ecozone and ecoregions, with the Mixed Grassland being the least affected. Furthermore, the highly fragmented and dispersed nature of remaining native lands is producing a further 'islandizing' effect on their ecological integrity. This, together with the continuing loss of native prairie, means that an accelerated rate of species loss will occur as hostile ecological forces, such as introduced species and pesticides, act upon these fragments. The situation is urgent. We recommend that Saskatchewan's new Prairie Conservation Action Plan be implemented as soon as possible and that efforts be intensified to protect all remaining native lands from cultivation.

INTRODUCTION

Estimates of the status of native biodiversity are often confounded by limitations in knowledge. For example, it is difficult to estimate losses in biodiversity when a large proportion of a particular biota has not been scientifically described, or if information is imprecise on the extent to which native habitats have been altered. Such is the case for southern Saskatchewan. While estimates of native prairie loss in the province have been published (Adams and Didiuk 1993, Epp 1992, Rowe 1987, Sugden and Beyersbergen 1984, Wiens 1993), the exact extent to which this has occurred and its implications for terrestrial biodiversity have not been properly assessed. However, with the advent of satellite technology, it has now become possible to generate accurate estimates of the extent of remaining native prairie (Polson 1993). In this light, this paper has three objectives:

- To quantify the extent and distribution of remaining natural habitats in southern Saskatchewan from satellite images.
- To estimate the loss of prairie biodiversity to date.
- To evaluate the risk to remaining prairie biodiversity.

METHODS

Saskatchewan Environment and Resource Management is one of the partners of the Southern Digital Land Cover Project which is working to produce digital maps of vegetation cover from 1996 satellite images (30 meter resolution). At this time, 126 1:50,000 map sheets have been delivered and the remainder are expected soon. Of these, 35 covered the Mixed Grassland Ecoregion, 23 covered the Moist Mixed Grassland Ecoregion, and 30 covered the Aspen Parkland Ecoregion. These were taken as representative samples of each ecoregion and were analyzed with respect to their vegetation cover (Figure 1). For each map sheet and ecoregion, the proportion of remaining natural habitats consisting of native grasslands, shrubs and hardwood trees was determined. These proportions were then used to estimate the loss of native biodiversity through the use of species-area curves in which the logarithm of the proportion of original native habitat remaining is plotted against the logarithm of the proportion of remaining species (MacArthur and Wilson 1967, Meffe and Carroll 1994). A number of studies for a variety of taxa has shown that the slope of this relationship lies between 0.2 and 0.35 so these were taken as the low and high values for this study (Meffe and Carroll 1994, Figure 2). Finally, the number and size of remaining natural habitat patches were quantified for each of the ecoregions.

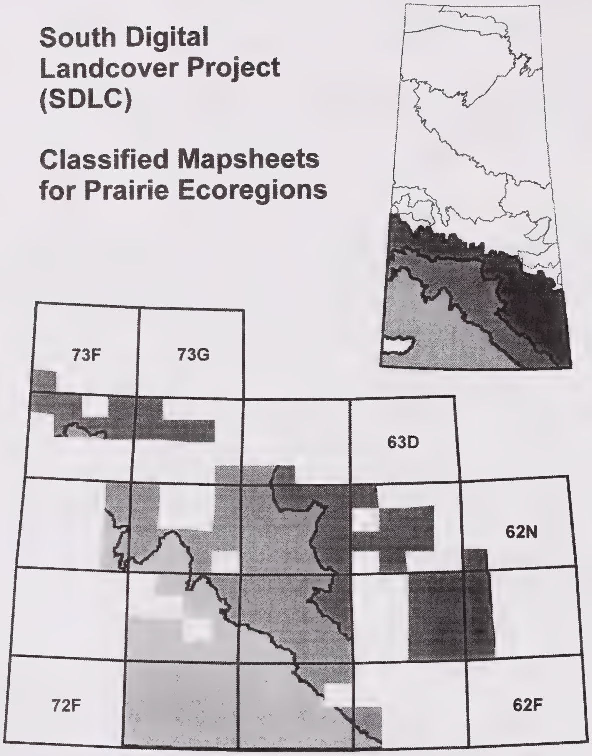

Figure 1. Distribution of 1:50,000 map sheets used for the analysis.

RESULTS

Analysis of vegetation cover for the Mixed Grassland, Moist Mixed Grassland and Aspen Parkland Ecoregions revealed that 31%, 14% and 24% remains as natural habitat respectively. Combined overall, there is 23% of the three ecoregions still in some form of natural habitat. Plotting these values against the species-area curves for both low and high slope values predicted that 21 to 34%, 33 to 50% and 25 to 39% of the native biodiversity has already been extirpated from the three ecoregions respectively. Combined overall, the predicted loss was 25 to 40%. The number and size of remaining natural habitat parcels in the three ecoregions are shown in Table 1. Only about 1% of the areas are greater than 100 ha in size.

DISCUSSION

The estimates of terrestrial biodiversity loss in southern Saskatchewan given above should be interpreted with some caution. Not all taxa are going to be affected to the same extent by the conversion and fragmentation of native habitats. For example, some species can, and do, exist in the altered ecosystems. This would lead to an overestimate of the level of extirpation based on species-area considerations alone. However, other factors would lead us to underestimate extirpation rates. For example, not all species were distributed evenly over the landscape prior to its fragmentation. Less widespread species would be more affected by habitat reduction. Another factor is the status of the remaining habitat. In southern Saskatchewan, it is split into many small pieces and further “islandizing effects” come into play. For example, invasion by non-native species, the loss of natural disturbances, and pesticide encroachment will be more acute for smaller areas. Extirpation estimates are also a function of the taxa involved. Species that are “area dependent” or with a limited ability to disperse will be more affected by habitat loss and fragmentation. With only about 1% of the remaining natural areas in southern Saskatchewan greater than 100 ha (Table 1), the current situation is critical. Research on grassland birds has shown that areas of less than 200 ha

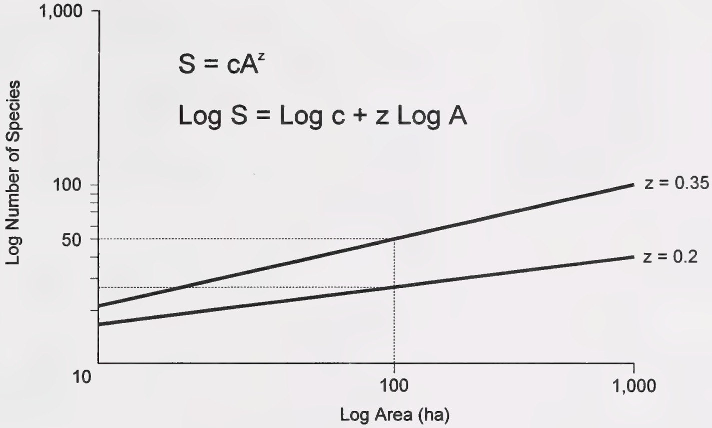

Figure 2. Species-area curves used to estimate the impact of habitat loss on native biodiversity in southern Saskatchewan.

do not support the full complement of species (SWCC 1997, Vickery et al. 1994). If birds are any indication, much of Saskatchewan's remaining prairie biota is at extreme risk of extirpation unless native habitats are protected from conversion. Owing to the logarithmic nature of the species-area relationship, additional further losses of native habitat in the future will result in disproportionate losses in native biota.

RECOMMENDATIONS

Despite the growing awareness of the plight of native prairie in Saskatchewan and elsewhere (Samson and Knopf 1996), the biggest threat to its existence is still cultivation, in which its long-term economic benefits are traded off over the short-term. Elimination of many of the government subsidies for agriculture is helping to correct this myopia; however, the native prairie of Saskatchewan is still seen by many people as something waiting to be "developed", rather than as an economic entity unto itself. The new Saskatchewan Prairie Conservation Action Plan (PCAP Committee 1998), spearheaded by the Saskatchewan Stock Growers' Association, sets out a number of objectives that need to be achieved if this valuable but diminishing resource is to survive the next few decades and the predicted doubling of world population. This plan should be adopted and implemented at all levels of provincial society. The government should do its part by changing policies that promote the conversion of native prairie. Perhaps "Provincial Grasslands" should be created that would be analogous to our Provincial Forests. The conservation of native habitats on private lands should be encouraged through the use of conservation easements. Native prairie habitats can, and do, pay for themselves over the long-term once their inherent values are recognized. The ranching community has known this for 100 years. Will the rest of us finally listen?

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Table 1. Number and size of remaining natural habitat patches in southern Saskatchewan by ecoregion. Sample sizes refer to number of 1:50,000 map sheets examined.

	< 10 ha	11-100 ha	101-1,000 ha	> 1,000 ha
Mixed Grassland (n = 29)	30339	2017	372 (1.1%)	80 (0.2%)
Moist Mixed Grassland (n = 18)	23444	1042	192 (0.8%)	43 (0.2%)
Aspen Parkland (n = 12)	24346	888	144 (0.6%)	16 (0.1%)
Overall (n = 88)	116912	5637	980 (0.8%)	192 (0.2%)

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STATUS OF BLACK-TAILED PRAIRIE DOGS IN CANADA

P.J. Fargey

Grasslands National Park, P.O. Box 150, Val Marie, Saskatchewan S0N 2T0

D.A. Gauthier

Canadian Plains Research Center, University of Regina, 3737 Wascana Parkway, Regina, Saskatchewan S4S 0A2

C.H. Schroeder

Natural History Society, Box 291, Regina, Saskatchewan S4P 3A1

W. Harris

Saskatchewan Environment and Resource Management, 350 Cheadle Street W., Swift Current, Saskatchewan S9H 4G3

Abstract: Historical and current information on black-tailed prairie dog numbers and their distribution in Canada is reviewed and discussed within the context of conservation and management issues. The historical area of occupation of prairie dogs in Canada is described in terms of ecosystem characteristics and land use trends. Primary and secondary sources regarding historical information about prairie dog numbers, distribution and densities are reviewed. Current numbers, distribution and densities are reviewed. Current numbers, distribution, densities and trends are presented, including details on habitat. A summary of on-going research is presented. Conservation and management issues are discussed in relation to (a) the ecological role of prairie dogs, (b) land use conflicts, (c) threats to conservation, (d) restoration and recovery requirements, (e) legislation and management programs, and (f) required research.

REPTILES AND AMPHIBIANS OF PRAIRIE CANADA: "THE HIDDEN BIODIVERSITY"

Andrew B. Didiuk

Canadian Amphibian and Reptile Conservation Network, 115 Perimeter Road, Saskatoon, Saskatchewan S7N 0X4

Abstract: The prairie provinces of Canada have a surprising variety of amphibian and reptile species. Some species are typical of the grasslands, parklands, mixed wood and boreal forests but many others are at the edge of their North American ranges and are typical of more arid regions to the south, of more moist regions to the southeast, or montane regions to the west. Most species are difficult to detect except during specific periods when they aggregate, such as breeding choruses of some amphibians and wintering at hibernacula for some species of snakes. Activity is highly governed by air temperatures and/or moisture, and under unfavourable conditions they may remain under cover for long periods of time, be active for short time periods, or only be active at night. Perceptions of distribution and abundance are strongly affected by these behaviours. The importance of amphibians and reptiles in the functioning of ecosystems is often underestimated. In many wetland habitats amphibians prior to metamorphosis can exceed all other animal biomass, can affect other animals through predation and competition, and are preyed upon by many other species of vertebrates and invertebrates. They efficiently convert biomass, with little converted to energy because they are ectotherms, and they are an important means of transfer of energy between wetland and terrestrial environments when larvae transform and disperse. Because many species mature slowly and are long-lived, amphibians can act as energy reserves within ecosystems. Turtles are important predators within wetlands, and snakes can consume large numbers of mammalian and avian prey in terrestrial habitats.

There has been increasing interest in the diversity of species, or "biodiversity", in prairie Canada among biologists, land managers and naturalists, who use a variety of working definitions and measurements of biodiversity. This interest is important for the conservation and stewardship of flora and fauna of the prairie ecosystems since it addresses the linkages among the many biotic and abiotic components of the prairie grasslands and aspen parklands (e.g. Rowe 1997). An ecosystem approach to conservation, protection and enhancement of flora and fauna is necessary, yet single-species projects are still needed to address some species with populations at risk.

There has been far less study, and understanding, of populations of amphibians and reptiles, compared to a wealth of information about birds and mammals, in prairie Canada and many other regions. The secretive nature of many amphibians and reptiles, and the difficulty in actually detecting the presence of some species, often results in the creation of a list of those species "likely present" during biophysical inventories such as environmental impact assessments. To be fair this is understandable since significant resources, labour and field costs, are necessary to simply confirm the presence of some species! It is encouraging, however, to see increased interest in and funding of amphibian and reptile research and population assessment in recent years within the academic community, by government wildlife agencies, and during environmental impact assessments.

Because of the difficulty in detection and surveying of amphibians and reptiles, we probably underestimate both their abundance and the function in aquatic and terrestrial habitats. Amphibians and their larvae can be extremely important in wetlands where they affect aquatic flora and other animals through predation, grazing and competition. High densities of amphibian larvae can occur in small prairie wetlands, where they display density-dependent responses to these high densities: variable growth, survivorship, and length of the larval period (e.g. Semlitsch and Caldwell 1982). Densities of larvae and their combined biomass can be very large for tiger salamanders (*Ambystoma tigrinum*) in North Dakota, with a maximum density of 5000 larvae per hectare, and a maximum biomass of 182 kg per hectare (Deutschman and Peterka 1988). By mid-July, when tiger salamander larvae are near to metamorphosis, annual production of larvae can be up to 565 kg per hectare. Single passes of an 8 m beach seine in dugouts in southeastern Alberta have captured more than 1000 tiger salamander larvae (Didiuk 1998).

Amphibian larvae are important grazers of aquatic vegetation, algae and detritus, and are important predators upon aquatic vertebrates, and are highly efficient in converting this biomass to their tissues. The movements of breeding adults to wetlands, and the dispersal of new metamorphs from wetlands, represent an important transfer of energy between terrestrial and aquatic ecosystems. Large numbers of juvenile, subadult and adult amphibians may be dispersed in the vicinity of prairie wetlands, and it would be interesting to compare their combined biomass with that of prairie small mammals and songbirds combined! This biomass is available to many aquatic and terrestrial predators. Amphibians are ectotherms, do not expend energy to maintain body heat, and can act as energy reserves within ecosystems (Stebbins and Cohen 1995). They are relatively long-lived, have high fecundity, and can exploit breeding habitat when it becomes available.

Reptiles are also an important but often undetected component of both aquatic and terrestrial environments in the prairie grasslands and aspen parklands, where they prey upon a wide variety of vertebrate and invertebrate species. Prairie rattlesnakes (*Crotalus viridis viridis*) and bullsnakes (*Pituophis melanoleucus*) are predators of small mammals, and they can consume a large proportion of the standing biomass of small mammal populations (e.g. Wallace and Diller 1990). Snakes themselves, particularly neonates and juveniles, are preyed upon by a wide variety of bird and mammal species. Turtles are important omnivores in aquatic habitats.

The influences of temperature and humidity are the most important factor which make detection and monitoring of amphibians and reptiles a difficult task. Outside of their preferred temperature range most species are under cover of some type and not visible. Degree of vagility, and cryptic colouration and behaviour, also limit their detection. In contrast to more southern areas, with greater numbers of species and overall greater abundance of amphibians and reptiles, in prairie Canada there are few species and populations are often small or widely dispersed. Traditional search techniques, area- or time-constrained, are usually unproductive.

Sedentary species are difficult to detect and monitor through the use of passive monitoring tools such as traps, since trapping efficiency is directly related to degree of movement of the target species. The plains hognose snake (*Heterodon nasicus nasicus*) is a good example of a species which may be quite sedentary and therefore difficult to detect. In contrast, seasonal movements of other snakes (e.g. prairie rattlesnake, garter snakes) from wintering sites to foraging areas can be often detected since large numbers move long distances. Fossorial behaviour of many species of reptiles and amphibians makes them difficult to detect unless they are undertaking seasonal movements which can be intercepted by traps, or if they concentrate (e.g. breeding choruses of frogs and toads). Cryptic colouration and behaviour limit our ability to detect the presence of some species despite intensive foot-searching of their habitat (e.g. short horned lizard, *Phyrnosoma hernandezi*). Intermittent breeding, with reduced or no breeding in dry years (e.g. great plains toad, *Bufo cognatus*), or explosive breeding of short duration (e.g. plains spadefoot toad *Scaphiopus bombifrons*), limit our ability to monitor population trends, or even delineate areas where these species are present!

However, there are behaviours which do allow the detection and assessment of amphibian and reptile populations. The most familiar one is the congregation of frogs and toads in spring breeding choruses. The loud calls of males of many species does allow more efficient confirmation of presence and distribution of many species. The aggregation of some species of snakes at hibernacula for the winter can allow access to large numbers of individuals, although the detection of these wintering sites is itself challenging. Movements of large numbers of individuals to and from wintering sites and breeding or foraging areas can allow confirmation of presence and indices of abundance among years (e.g. movements of tiger salamanders to and from breeding ponds, movements of prairie rattlesnakes to and from hibernacula). Use of specific features of habitat can facilitate surveying and monitoring techniques (e.g. basking sites of aquatic turtles).

Surveys should take advantage of these aspects of amphibian and reptile behaviour which improve their detection. The great plains toad has been considered to be a threatened species in southeastern Alberta, based on surveys during a period of drought. More recent surveys under appropriate water conditions have revealed many breeding locations at CFB Suffield National Wildlife Area and adjacent regions (Didiuk 1998, L. Powell, pers. commun.). The plains spadefoot toad has been a difficult species to detect due to its explosive breeding and very brief calling period of 1-2 nights after heavy rainstorms, and there have been few records in prairie Canada. However, recent concerted efforts to detect this species under appropriate conditions have resulted in many new locations and enlargement of its known range in both Alberta (Klassen 1998, Lauzon and Balagus 1998) and in Saskatchewan (A. Didiuk, unpubl. data). The plains hognose snake is probably a sedentary species, is highly fossorial, may have limited daily activity periods above ground, and is relatively small and cryptic in colouration. There have been few records of this species in prairie Canada, and it has been considered to be rare and perhaps highly localized in its distribution. However, a recent study using drift fences to intercept movements of snakes at CFB Suffield National Wildlife Area has resulted in many new records of this species in a variety of habitat types (Didiuk 1998). These examples illustrate that some species may not be as rare as the small number of reports would suggest. Difficulty of detection, and the lack of sufficient effort - "seek and ye shall find" - make some species appear to be rare when they may actually be locally abundant.

The total number of species of amphibians and reptiles in prairie Canada, 31, is low compared to areas farther south (Table 1). However, most regions do have an interesting variety of both amphibians and reptiles. These populations do, or may, exhibit adaptations to marginal conditions for reproduction, growth and survival. The temperate climate, with long cold winters and short but warm summers with frequent drought, requires adaptations to deal with mortality and limited foraging time. Intermittent breeding of amphibians and some snakes, aggregation at optimum wintering sites, and high dispersal abilities are some adaptations to these environmental limitations.

The range of each species of amphibian and reptile was delineated by including all prairie ecodistricts which are totally or partially within the estimated ranges. This approach is an approximation since the limits of the ranges for most species are not well known, and in some cases inclusion of some of the larger ecodistricts probably overestimates their actual range. However, it is a useful first approximation for range delineation. Species richness maps were prepared for amphibians (Figure 1), reptiles (Figure 2) and both amphibians and reptiles (Figure 3). The greatest number of amphibian species are found in the southeastern portion of Manitoba where some species reach the northwestern edge of their range (e.g. mink frog, *Rana septentrionalis*; spring peeper, *Hyla crucifer crucifer*; mudpuppy, *Necturus maculosus maculosus*) (Figure 1). Reptile species are also more abundant in southern prairie Canada, particularly in extreme southern Saskatchewan where some species at or near the northern edges of the ranges (eastern yellowbelly racer, *Coluber constrictor flaviventris*; prairie rattlesnake; short-horned lizard; plains hognose snake) (Figure 2). Combined numbers of amphibian and reptiles species are most abundant in these two southern areas, and along the foothill regions of western Alberta where some alpine species of amphibians occur (long-toed salamander, *Ambystoma macrodactylum*; spotted frog, *Rana pretiosa*; boreal toad, *Bufo boreas*).

Table 1. Numbers of species of amphibians and reptiles in prairie Canada.

Species Group	Manitoba	Saskatchewan	Alberta	Total
Frogs	8	3	4	9
Toads	4	3	4	5
Salamanders	3	1	2	4
Amphibians	**15**	**7**	**10**	**18**
Turtles	2	2	1	2
Lizards	1	1	1	2
Snakes	5	9	6	9
Reptiles	**8**	**12**	**8**	**13**
Combined	**23**	**19**	**18**	**31**

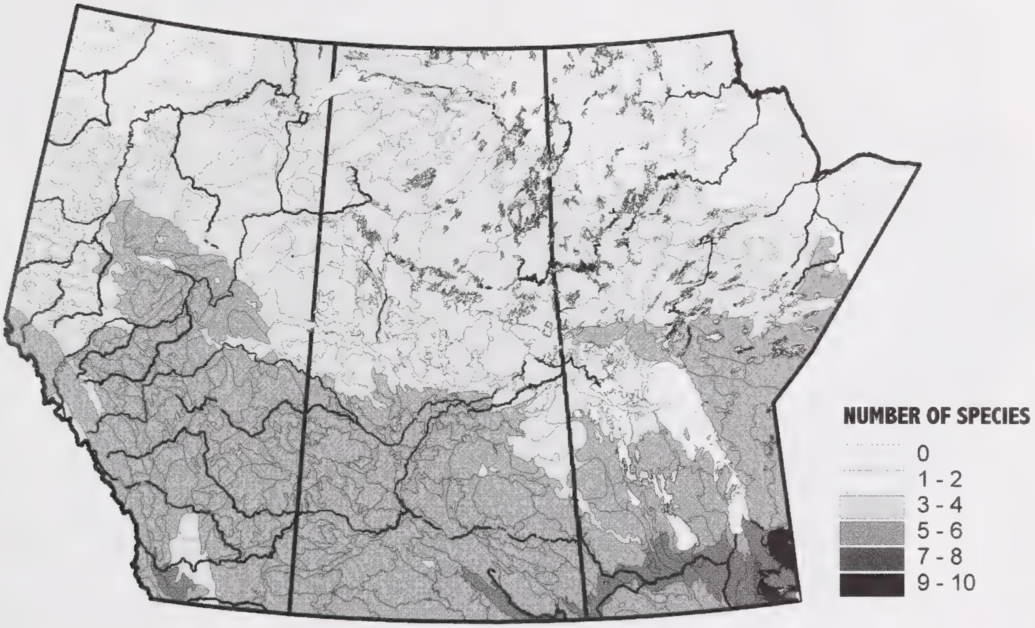

Figure 1. Number of amphibian species in prairie Canada.

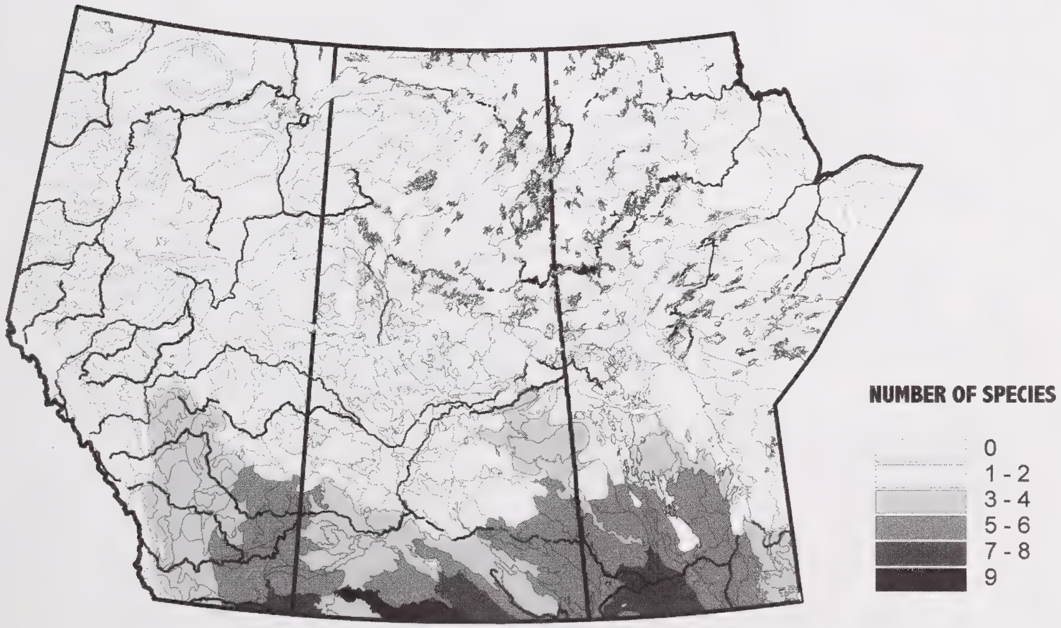

Figure 2. Number of reptile species in prairie Canada.

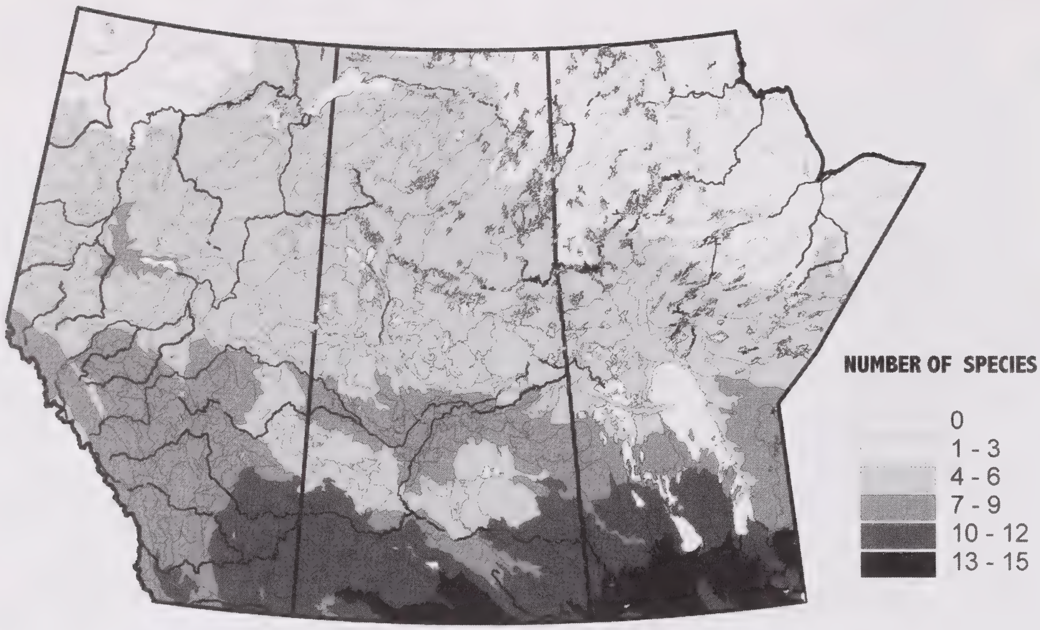

Figure 3. Number of amphibian and reptile species in prairie Canada.

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BURROWING OWL CONSERVATION IN CANADA

Geoff Holroyd

Canadian Wildlife Service, 200 - 4999 98th Avenue, Edmonton, Alberta T6J 1Z1

Abstract: In Canada, the burrowing owl is endangered and its numbers are rapidly declining. There are fewer than 1000 pairs left in Canada, all in southern Alberta and Saskatchewan where more than 3000 pairs nested in 1978. The number is declining over 10% per year even though over 700 landowners are voluntarily, through Operation burrowing owl, protecting over 37,000 hectares (93,000 acres) of grassland habitat that was used by nesting owls. The last pair nested in Manitoba in 1986, down from 76 pairs fifteen years earlier. There is one pair know in B.C. after a ten-year reintroduction effort. One of the factors implicated in the burrowing owl's decline in its apparent low productivity. In Canada, this owl has an average clutch size of 9 eggs but fledges only 3-5 young. A food supplementation experiment indicates that the wild food supply is inadequate for this species to reach its reproductive potential. Mortality includes: nest predation (20-50%) mostly by badgers: post-fledging juvenile mortality (65%), of which 70% was caused by raptors and 30% by coyotes; post-fledging adult mortality (27%), caused by raptors. Annual adult return rates on the breeding grounds are 40-55%. Other possible mortality factors are starvation, pesticides, collisions with vehicles, shooting, and predation and habitat loss on migration and wintering areas.

SIX DECLINING GRASSLAND RAPTORS: CHANGES SINCE THE 1960S

C. Stuart Houston

863 University Drive, Saskatoon, Saskatchewan S7N 0J8

Abstract: Since the 1960s there have been major population declines involving three vole-eating raptors, the northern harrier, short-eared owl, and long-eared owl. The first two are ground nesters. The Saskatchewan burrowing owl population is evidently on the road to extirpation, with disappearance of breeding colonies and pairs from all nine Community Pastures in the Kindersley area. Might drops in these raptors be in some way connected to whatever factors, in the same region, are contributing to drops in many smaller grassland birds, such as killdeer, Sprague's pipit, chestnut-collared longspur and western meadowlark?

Both grassland buteos, the Swainson's hawk and ferruginous hawk, simultaneously showed nine consecutive years, 1988-1996, of unprecedented drops in productivity. Swainson's hawk numbers by 1996 had dropped to half of what they were in 1987.

There is one item of good news. The Merlin virtually disappeared from the plains in synchrony with dieldrin use in the 1960s, but has since rebounded to something near its historic population levels and has followed corvids into the cities.

A raptor banding program, centered on Saskatoon but with 30 summers of special effort directed to the grasslands between Kindersley and the Saskatchewan-Alberta boundary, has allowed me to follow populations and productivity of ten raptor species. Six of these species have declined in numbers or productivity and one has recouped from near-extirpation following use of dieldrin around 1960. We have only glimmerings as to the cause of the other declines. I wish to review my own studies that have been published or are in press.

Not all raptors have declined. Local populations of the golden eagle and prairie falcon, restricted mainly to the badlands and cliffs of the South Saskatchewan River and its coulees, seem stable. The red-tailed hawk, extremely rare in grasslands in the first decade of this study, has moved south in ever-increasing numbers. It does not seem to drive out the Swainson's and ferruginous hawks but fills empty niches as they appear.

The most striking decline has been that of the burrowing owl, (covered by the previous speaker, Geoff Holroyd). The last known breeding pairs of burrowing owls in the large community pastures west and north of Kindersley were as follows: Antelope Park, 1980; Heart's Hill, 1985; Mantario, 1986; Hillsburgh, 1986; Newcombe, 1990; Eagle Lake, 1993; Progress, 1994, and Mariposa, 1996 (Houston, Hjertaas, Scott and James, 1996). There has been insufficient change in habitat on these pastures to explain this continuing regional extirpation, although before 1978 almost 20% of the pasture area was planted to tame grass.

Assessment of long-term trends for three other raptor species, the northern harrier, short-eared owl and long-eared owl, are difficult because all three are cyclical and highly responsive to vole numbers. Voles were extremely common or even super-abundant on three occasions, in 1960, 1969 and 1997. Each of these years involved a most unusual circumstance whereby appreciable acreages of grain lay unharvested beneath relatively deep snow over winter in a number of Saskatchewan localities. The northern harrier, described by Hamerstrom (1986) as "the hawk that is ruled by a mouse," responded in each of these vole years by laying larger egg sets and fledging more young. This partially masked but could not fully obscure a widely recognized long-term decline, confirmed by Breeding Bird Surveys (BBS).

The short-eared owl was, through the 1970s, seen mainly as a spring and fall migrant near Saskatoon, but in the Kindersley area it was a regular summer resident of grasslands. By the 1990s, individuals were rarely encountered in summer, a decline supported by BBS results. Clearly nomadic, it responded in dramatic fashion to the increased vole populations in 1960, 1969, and 1997. No less than 63.5% of 246 of my nestling short-eared owls were banded in 1960 and 1969 alone. The majority of sightings in the Saskatoon Nature Society nest records scheme were from the years 1967 through 1969. One presumes that many of these owls were on their way farther north, perhaps destined for Arctic tundra, but the presence of voles encouraged them to stop over and nest. The nests found were mainly on stubble, and were destroyed during seeding or cultivation; if the farmer responded to the female flushing from her nest and left a conspicuous patch of stubble, this merely attracted crows, foxes and coyotes; few nests produced young.

It is more difficult to explain how the long-eared owl, normally an uncommon summer resident, both in parkland near Saskatoon and in grasslands near Kindersley, can suddenly appear out of nowhere in increased numbers, whenever vole populations peak suddenly. Nomadism must surely be a part of the explanation (Houston 1998, in press). The peak years of the long-eared owl coincided with peak numbers of voles and of short-eared owls, and 35.1% of nestlings banded were in the two exceptional years, 1960 and 1969. There have since been two summers without a single sighting of the long-eared owl, either at Saskatoon or at Kindersley, but usually one or two nests are located.

My studies have concentrated mainly on banding young of the two grassland buteos, the Swainson's hawk and ferruginous hawk. Here solid evidence exists for a decline in productivity from 1989-1996. Continued ploughing of grassland; deterioration of shelterbelt trees from drought, chemical sprays, neglect, and bulldozers; the greatly increased numbers of the red fox (virtually unknown before 1965-66 and increasingly common since the 1970s) and coyote, and a crash of grasslands populations of Richardson's ground squirrels since 1987, are all possible factors, though I believe the last two to be the most important.

Nine years of declining productivity of Swainson's hawks near Kindersley began in 1988; in the first six years productivity declined from 2.09 to 1.27 young per successful nest, then rose slightly to 1.83 in 1994, then dropped to only 1.49 and 1.48 in 1995 and 1996, the second and third worst years since 1969. Similarly, ferruginous hawks fledged an average of 3.01 young per successful nest from 1969-1987 (n=369). Since then productivity has shown a decline, averaging 2.69, but below 2.82 in each year (n=433, r=0.63, p=<0.001; Houston and Schmutz 1998, in press).

The raptor problem is made more worrisome because it is mirrored by continuing declines in numbers of smaller grassland specialists. When I began my visits to Kindersley, there was a constant aerial canopy of song, consisting chiefly of Sprague's pipits, chestnut-collared longspurs and horned larks; all have since decreased noticeably. BBS data show that the grassland guild is declining more rapidly in Canada than birds of the forest or scrub guild (Downes and Collins 1996). For example, in the Canadian prairie provinces between 1966 and 1994, significant declines occurred in Sprague's pipit (7.3% each year), loggerhead shrike (5.6%), killdeer (3.3%); short-eared owl (2.9%), northern harrier (2.2%), western meadowlark (2.1%), and burrowing owl (2.0%). The process is not confined to migratory birds; larger, year-round grassland birds such as sharp-tailed grouse and sage grouse have also shown major declines (the latter evident from a fine poster at this symposium).

Finally, there is a good news story, that of the Richardson's merlin. It is extremely fortuitous that Kindersley was also the site of merlin studies dating from the late 1950s by Glen Fox, Richard Fyfe, and then Keith Hodson, who did his master's study in 1972-1974. Merlins declined in numbers and productivity near Kindersley, from 1958-60. The sole surviving pair in 1962 was the last to be recorded until one pair was found near Marengo in 1972. Meanwhile, dieldrin use had been restricted in 1965 and banned in 1966. Habitat loss also occurred: 52% of the merlin's grassland hunting territories present in the 1940s had been cultivated by 1971. Richard Fyfe's observations and mine, from 1969-74, failed to locate any further pairs until I found a single pair each in 1975 and 1976. Merlins then gradually increased, with excellent productivity; 55 of 125 nests through 1995 raising five young to banding age (Houston and Hodson 1997). Here the cause and effect were evident, the chemical was banned, and after a lag of six to nine years, recovery occurred gradually. Merlins then followed corvids, who provided nests for them, into the cities.

The burning question is why grasslands have sustained declines in numbers and productivity among raptors, small migrants and resident upland game birds, beyond those sustained in other habitats. For example, Swainson's hawk productivity has been maintained in parkland regions, during the years of decline in grasslands. Which of the possible factors mentioned above have contributed most to the declines documented here? What can be done? Research is needed before other species go the way of the burrowing owl.

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SOIL MICROFAUNA DIVERSITY IN PRAIRIE ECOSYSTEMS

O. Olfert, M.P. Braun, S.A. Brandt, and A.G. Thomas

Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, Saskatchewan S7N 0X2

Abstract: Profitability and soil degradation are major issues facing farmers in the grassland ecozone of the Canadian Prairies. Producers are encouraged to diversify away from cereal monoculture and to reduce fallow and inputs to address these issues. However, climatic and economic considerations do restrict what can be grown. This study was initiated to monitor and assess alternate input and cropping strategies with respect to (i) biodiversity (ii) pest dynamics (iii) farm profitability (iv) soil quality (v) food safety. The experimental framework of nine different cropping systems is based on a matrix of three levels of input use and three levels of cropping diversity. Evaluations are done on an annual or cyclical basis (6 year), to determine rate and direction of change over time. The design, data collection and evaluation are based on the collaborative efforts of crop, pest, economic and soil scientists. Soil arthropods are a major component of the evaluation. In addition to the nine cropping systems, the diversity of arthropods was evaluated in native prairie, in a 50-year old grass ecosystem and in grassy field margins. A baseline data set containing density and diversity of arthropods found in and on the soil has been compiled; the effect of long-term rotations and farming systems on arthropods is being evaluated. The anticipated outcome is: (i) to provide guidance for development of systems that maintain food quality and quantity without increasing inputs of non-renewable resources; and (ii) to develop biological indicators which reflect the status of such systems.

THE PROBLEM

Society in general, and agriculture in particular, are being challenged to develop practices that preserve the natural processes that sustain our ecosphere. Profitability, diminishing land resources and land degradation are major issues facing farmers in the grassland ecozone of the Canadian Prairies. The desire to maintain the capacity of the soil to sustain biological productivity has positively influenced the study of soil properties that contribute to the quality and health of our prairie soils. Acton and Padbury (1993) defined soil quality in terms of measurable soil properties that influence the capacity of the soil to perform crop production or environmental functions. Doran and Safley (1997) defined soil health in terms of a living system that has the capacity to sustain biological productivity, promote the quality of air and water environments and maintain plant, animal, and human health. Producers in this part of the world are encouraged to diversify away from cereal monoculture and to reduce fallow and inputs to address these issues. However, climatic and economic considerations do restrict what can be grown. Alternative production systems have been suggested to meet the demands for food and fibre while preserving the ability of future generations to meet their needs. While some agricultural practices have been evaluated for their short-term impact on the capacity of soil to sustain production, few have been evaluated for their long-term impact on the components of a vital living system (Paoletti *et al.* 1993). The capacity of the soil to function as a vital living system is inherent in the concept of sustainable land management. Sustainable land management is defined here as:

> *Sustainable land management combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously: (i) maintain or enhance production/services; (ii) reduce the level of production risk; (iii) protect the potential of natural resources and prevent degradation of soil and water quality; (iv) be economically viable; and (v) be socially acceptable.*
>
> (Smyth and Dumanski 1993)

A mechanism to assess the health status of prairie soil resources is essential to the development of sustainable land management practices. The establishment of such an evaluation framework is confounded by the complexity of interactions among the biological, physical and chemical components of the soil. As a result, the design, data collection and evaluation must be based on the collaborative efforts of a multi-disciplinary team of crop, pest, economic and soil scientists. In addition, such evaluations often involve a long-term commitment to monitoring specific components within the agricultural system to determine rate and direction of change over time. It is anticipated that such an evaluation will identify attributes that are associated with changes in soil health. This, in turn, will contribute to our understanding of the impact of cropping systems on sustainable land management.

THE PURPOSE

This study was initiated to monitor and assess alternative input and cropping strategies based on three levels of production inputs and three levels of cropping diversity. The study will evaluate the different strategies over an 18 year period with respect to (i) biodiversity (ii) pest dynamics (iii) farm profitability (iv) soil quality (v) food safety. In addition to the nine cropping systems, the diversity of arthropods was specifically evaluated in fo ur uncultivated areas: native prairie, a 50-year old grass ecosystem, a 30-year old alfalfa/brome grass ecosystem and the grassy margins next to the study site. This paper describes the evaluations of the soil microfauna.

METHODS

All aspects of this study are located at the Agriculture and Agri-Food Canada Experimental Farm at Scott, Saskatchewan (52° 22'; 108° 50'). Scott is located in the Dark Brown soil zone; the area is categorized as moist mixed grassland.

Cultivated Crop Site

The cultivated site consists of 16 ha of farmland that have been under cultivation for about 80 years; the soil type at the site is categorized as a mixed Scott and Weyburn loam. The study began in 1994 with a uniform cropping of barley. An extensive site characterization of physical and biological components was conducted that same year. The experimental framework of the cropping portion of the study is based on a matrix of three levels of input use and three levels of cropping diversity. The three levels of inputs are assigned to main plots in a split-plot factorial design. Large plot size (75m x 40m) is used to preserve input treatment integrity. In total 215 plots were involved. The input levels are described as:

1. Organic. Pest control and nutrient management are based on non-chemical means.
2. Reduced. Integrated long-term management of pests and nutrients.
3. High. Pesticides and fertilizers are used 'as required'.

The three levels of cropping diversity are assigned to sub-plots within each main plot to enhance detection of diversity level differences. The levels of cropping diversity follow a six-year rotation and are described as:

1. Low. Fallow-wheat-wheat-fallow-canola-wheat.
2. Annual Grains. Canola-fall rye-pea-barley-flax-wheat.
3. Grain/Forage. Canola-wheat-barley-brome/alfalfa- brome/alfalfa-brome/alfalfa.

Uncultivated Sites

The native grass site is located on Weyburn loam and is approximately 3-4 ha in size. The site has not supported any livestock for about 30 years but the grass stand is cut for hay every 5-8 years. The old grassland site is located on Scott loam and is also approximately 3-4 ha in size. This site was cultivated approximately 50 years ago and seeded back to mixed grass shortly thereafter. It also has been treated similarly to the native grass site for the last 30 years. The alfalfa/brome grass site is also located on Scott loam and is 16 ha in size. It was cultivated and seeded to an alfalfa/brome grass mix about 30 years ago; the forage is harvested annually. The grass area in the fence line adjacent to the crop study site is about 5 m wide and is comprised primarily of crested wheat grass. The field plot margins were seeded about 40 years ago and are mowed several times during the summer months.

Sampling and Extraction Methods

Biological activity in soils primarily takes place in topsoil, and is concentrated in the top 5-10 cm. To assess the soil microfauna, soil cores (4 cm in diameter at 15 cm depth) were collected from all test sites in 1996, at three different times during the year. At the crop study site, four cores were taken from the odd-numbered subplots (n = 108). At the uncultivated sites, four replicates of four soil cores were taken at random from within each area. The samples were stored at +2° C until being placed in extraction funnels. Tullgren funnels and Baermann funnels were used to extract the organisms from the soil.

Tullgren funnels use heat and light to force arthropods living within the soil into a container of alcohol at the bottom of the funnel stem. The arthropods have been sorted and counted. The mites were sorted into four suborders; Actinendida, Acaridida, Gamasida, and Orabatida. Some mites were saved in alcohol and others were mounted on slides for further identification. The remaining micro-organisms such as nematodes and enchytraeids (Annelida) were also counted and sorted. Collembola and the larvae of Diptera and Coleoptera were sorted to the family level when possible.

Baermann funnels also use light and the heat to force organisms living in the soil water from the soil. Nematodes, rotifers, enchytraeids (Annelida) and protozoa were counted alive under a microscope with a dark background.

THE FINDINGS

The results of the Tullgren funnel extractions in 1996 indicated that Acari (mites) outnumbered the other arthropods at all sites. Within the Acari, four sub-orders predominated, Oribatida, Gamasida, Actinedida and Acaradida. Oribatid mites were most common in the native prairie, and decreased in number with the level of disturbance. Acaridida mites, on the other hand, increased in number with the degree of disturbance. Actinedid mites were most common in the alfalfa-brome grass site (Figure 1). Collembolans (springtails) were the predominant insect complex at all sites, ranging from 40% to 94% of the insects collected in the soil samples. Within this insect order, three families predominated, Isotomidae, Hypogastruridae and Onchyuridae. Isotomidae dominated the collembolan complex in the cultivated plots and in the crested wheat grass at the field margin. Hypogastruridae were most common in the native grass and the old grassland site. Onchyuridae were most common in the alfalfa-brome grass site.

The results of the Baermann funnel extractions indicated that nematodes outnumbered the protozoa, followed by the rotifers and enchytraeids (Annelida). Nematode abundance was highest in the native grass, followed by the old grassland, the crested wheat grass field margin, and the alfalfa-brome grass (Figure 2). The high input plots at the crop production site had the fewest nematodes. Protozoa followed a similar abundance pattern.

DISCUSSION

Soil microfauna are involved in a number of soil processes such as decomposition of organic matter, nutrient mineralization, regulating microflora (including plant pathogens) and decomposition of agricultural chemicals (Gupta and Yeats 1997). Protozoa, nematodes, rotifers and enchytraeids may have potential as indicators of soil health in contamination assessments because they tend to respond quickly to environmental changes in the soil. The constraint with these groups is that they require considerable technical expertise to identify groups or species. Soil arthropods were the other group that comprised a significant portion of the microfauna in this study. Because soil arthropods, such as Collembola and Acari, are relatively sedentary they do reflect the conditions of the soil habitat more than arthropods that are more mobile (van Straalen 1997). Micro-arthropods are abundant in agricultural soils but are often not studied in relation to soil processes (Crossley et al. 1992). Koehler (1992) reported that they are sensitive to agricultural chemical inputs and have

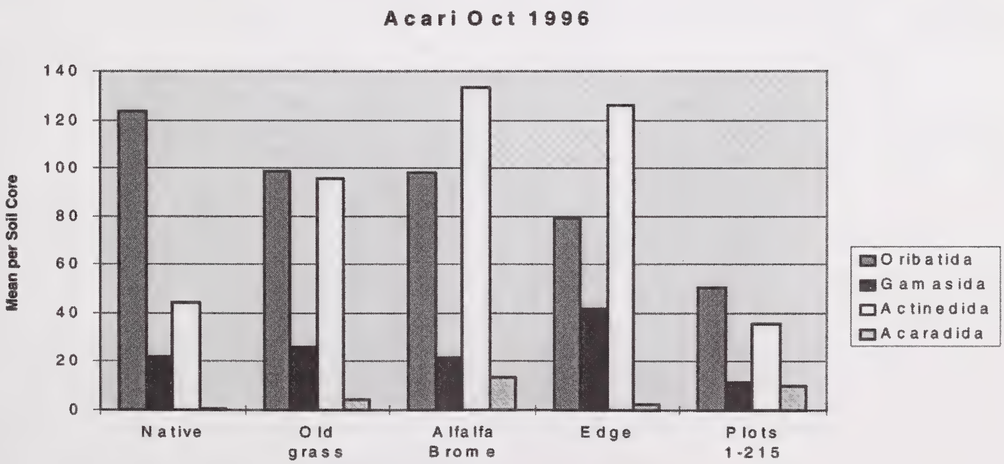

Figure 1. Mean number of mites (sub-orders) in different ecosystems at Scott, SK, in 1996.

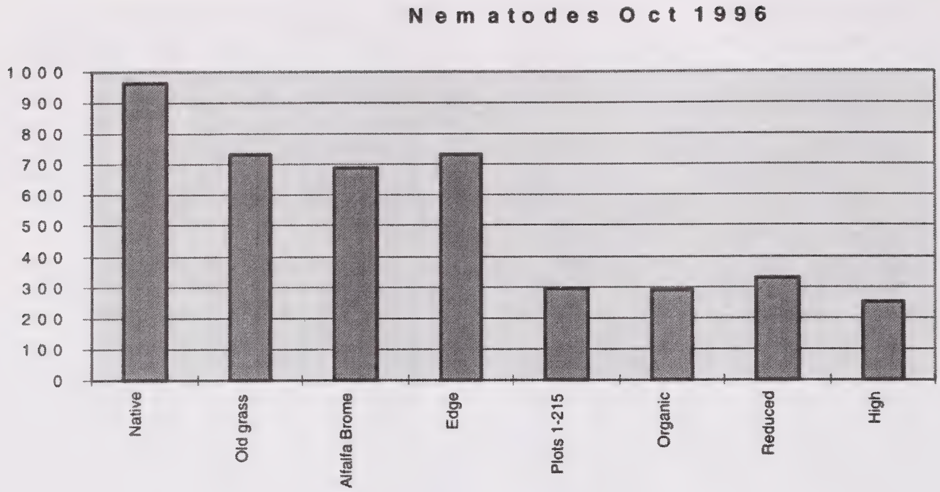

Figure 2. Total numer of nematodes in different ecosystems at Scott, SK, in 1996.

potential as biological indicators of the impact of chemicals on the ecosystem. Arthropod community composition may have more potential as an indicator of soil health than single species analysis (van Straalen 1997).

The results presented here represent a one-year snapshot of the soil microfauna at these sites in Saskatchewan. The future plans are to assess the direction and rate of change over time that are occurring in these components as a function of the different cropping systems (treatments). Evaluations will be conducted on an annual or cyclical basis (6 year). The design, data collection and evaluation are based on the collaborative efforts of crop, pest, economic and soil scientists. Soil microfauna are a major component of the evaluation. A baseline data set containing density and diversity of soil microfauna found in and on the soil has been compiled; the effect of long-term rotations and farming systems is being evaluated. The anticipated outcome is: (i) to provide guidance for development of systems that maintain food quality and quantity, without increasing inputs of non-renewable resources; and (ii) to develop biological indicators which reflect the status of such systems. These studies are intended to serve as a guide for the development of sustainable cropping systems that provide a stable food supply, do not increase inputs of non-renewable resources and preserve soil and environmental quality while maintaining or improving cropping potential.

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STATUS OF SMALL MAMMALS ON THE PRAIRIES: RESEARCH PRIORITIES AND IMPLICATIONS FOR CONSERVATION

Maria Pasitschniak-Arts and François Messier

Department of Biology, University of Saskatchewan, 112 Science Place, Saskatoon, Saskatchewan S7N 5E2

INTRODUCTION

Historically, the prairie landscape was characterised by extensive grasslands, aspen parklands, and an abundance of wetlands, all supporting a diverse array of native fauna and flora. Today, the prairies comprise the largest expanse of agricultural land in Canada, and are one of the most human-altered and fragmented landscapes in the country. While many habitat fragmentation studies have focussed on avian nest success (Pasitschniak-Arts 1995,1996,1998), particularly in forest ecosystems (Andrén1995, Murcia1995, Robinson et al. 1995), little work has been conducted on small mammals on the prairies.

There is growing interest regarding the importance of small mammal communities in prairie systems because their abundance and distribution may have important effects on community interactions. In addition, there is concern for suspected uncommon or rare species in federal and provincial parks, reserves, and wildlife areas, as well as on private lands. Virtually no reliable information exists for the "status", i.e., abundance and distribution, of small mammals in most areas of the Canadian prairies (Marinelli and Neal 1995, Pasitschniak-Arts and Messier in review). On federal wildlife areas, few small mammal studies have been conducted. For example, at Last Mountain Lake National Wildlife Area (NWA), the small mammal community has been described as moderately diverse, but only the common species have been recorded (Anweiler 1969, Driver 1983-1986, 1987) and the list is far from complete (Jorgenson 1987). At other wildlife areas, e.g., Stalwart NWA, no survey of small mammals has been undertaken (Caldwell 1984).

Although the status of small mammals has not been adequately investigated, small mammals are an important component of many ecosystems and landscapes. They consume a large variety of insects and seeds, and are a major food source for numerous species of generalist predators (Nowak 1991). Data on the status of small mammals will provide insight into their role in the prairie ecosystem. For example, avian predators such as parkland raptors, and particularly endangered species like the burrowing owl (*Speotyto cunicularia*), depend on small mammals as an important food source (Clayton 1997). Small mammals are also a major prey item for generalist mammalian predators such as striped skunks (*Mephitis mephitis*; Verts 1967), raccoons (*Procyon lotor*; Banfield 1987), red foxes (*Vulpes vulpes*; Samuel and Nelson 1983), coyotes (*Canis latrans*; Voigt and Berg 1987), and mink (*Mustela vison*; Arnold and Fritzell 1987). In habitats where populations of small mammals are high, these generalist predators have an abundant food source, and survival rate of duck nests may potentially be enhanced (Pasitschniak-Arts in review). In contrast, when populations of small mammals are low, generalist predators may turn to an alternative prey source, such as nesting birds and their eggs (Weller 1979, Angelstam et al. 1984, Pehrsson 1986).

In view of the importance of small mammals in many food chains, it is crucial to assess their status in various prairie habitats. The primary focus of this paper is to determine relative abundance, composition, and richness of small mammals in different habitat types and in different landscapes of the Canadian prairies.

STUDY AREAS AND METHODS

In spring and summer of 1996-1997, fieldwork was conducted in four different landscapes (i.e., treatment sites): Allan Hills, Willowbrook, and Baldur Assessment Sites, and at St. Denis NWA. All assessment sites cover an area of 6475 ha. The Allan Hills site is located approximately 80 km south of Saskatoon, and is considered a high treatment site, where approximately 20% of the study area is in the Prairie Habitat Joint Venture (PHJV) program. Willowbrook Assessment Site is located approximately 300 km southwest of Saskatoon, near the town of Yorkton. Baldur is located approximately 9 km southwest of Baldur, MB. Both Willowbrook and Baldur are moderately treated sites where PHJV habitats cover approximately 5% of the study area. Treated areas consist of a combination of dense nesting cover (DNC; mixture of alfalfa, brome, and wheat grasses) and native/idle grassland. St. Denis NWA, is a 385-ha region located approximately 40 km east of Saskatoon in the prairie pothole region of the province. St. Denis NWA is managed for wildlife and consists of approximately 40% untilled upland cover (a mixture of DNC and native/idle grassland) surrounded by cropland.

At all assessment sites and at St. Denis NWA, small mammals were sampled in five different habitat types: DNC, native/idle grassland, wetlands woodland, and cropland. Two fields of each habitat type were randomly selected, and within each field we ran two traplines, each consisting of 10 stations with two snap-traps at each station. Traps were baited with peanut butter, visited each morning and afternoon, and run for three consecutive days. In addition, two squirrel live-traps were placed at stations three and seven of every trapline to capture *Spermophilus franklinii* (Franklin's), *S. richardsonii* (Richardson's), and *S. tridecemlineatus* (thirteen-lined) ground squirrels. Small mammals were sampled once per month at each study site.

Relative abundance (RA) was measured as the number of small mammals captured per100 trap nights (TN). One trap night refers to one trap set over one night. Species richness refers to the number of species in each habitat type (Krebs 1989).

RESULTS

The prairies support a large diversity of small mammal species (Table 1). *Microtus pennsylvanicus, Peromyscus maniculatus*, and *Clethrionomys gapperi* were the three most abundant species, accounting for 90% of all captures. *Sorex cinereus* was the most common shrew, making up 4% of all small mammals caught. Two of the most uncommon species included *Microtus ochrogaster*, captured at Willowbrook Assessment Site, and *Onychomys leucogaster*, caught at St. Denis NWA. Ground squirrels made up approximately 1% of all captures. Juvenile ground squirrels occasionally were caught in snap-traps.

We first tested for habitat effect. Relative abundance of small mammals differed among habitat types (Table 2; Friedman ANOVA, $F_r = 9.9$, $n = 4$, d.f. = 4, $P = 0.04$). Pairwise multiple comparison revealed small mammal abundance to be significantly higher in woodland compared to wetland, cropland, native/idle grassland, and DNC ($P<0.05$). Differences among all other pairs were not significant. Species richness also varied among habitat types (Table 2; $F_r = 11.4$, $n = 4$, d.f. = 4, $P = 0.02$). Woodland, DNC, and native/idle grassland

Table 1. Relative abundance (RA = number captured/100 trap nights) of different species of small mammals on the Canadian prairies (1996-1997).

Species	Common name	RA
Microtus pennsylvanicus	meadow vole	3.6
Peromyscus maniculatus	deer mouse	2.2
Clethrionomys gapperi	southern red-backed vole	1.3
Zapus princeps	western jumping mouse	0.3
Sorex cinereus	masked shrew	0.3
Thomomys talpoides	northern pocket gopher	0.25
Sorex arcticus	Arctic shrew	0.05
Blarina brevicauda	short-tailed shrew	0.04
Eutamias minimus	least chipmunk	0.03
Microtus ochrogaster	prairie vole	0.007
Onychomys leucogaster	northern grasshopper mouse	0.007
Spermophilus tridecemlineatus	thirteen-lined ground squirrel	0.14
Spermophilus franklinii	Franklin's ground squirrel	0.11
Spermophilus richardsonii	Richardson's ground squirrel	0.1

Table 2. Median relative abundance, RA, (25, 75 percentiles) and species richness, SR, (25, 75 percentiles) of small mammals in different habitat types, (1996-1997).

Habitat	RA	SR
Woodland	14.7 (9.2, 19.9)	7 (6.5, 7.5)
Wetland	5.2 (3.9, 12.0)	5 (5, 5.5)
Cropland	7.2 (4.9, 12.6)	5 (4.5, 5.5)
Native grass	7.2 (5.8, 12.4)	5.5 (4.5, 6.5)
Dense nesting cover	7.0 (5.7, 10.8)	6.5 (6.0, 7.5)

showed higher species richness than cropland and wetland ($P < 0.05$); all other pairs were similar.

To determine if there was a treatment effect, we compared the RA of small mammals in the three Assessment Sites and at St. Denis NWA. Abundance of small mammals differed among treatment sites (Table 3; $F_r = 14.0$, $n = 5$, d.f. = 3, $P = 0.003$). Allan Hills supported a greater abundance of small mammals than either Baldur or Willowbrook ($P < 0.05$), and no difference was detected between Allan Hills and St. Denis. All other pairs showed similar RA. We detected no treatment effect on species richness (Table 3; $F_r = 0.21$, $n = 5$, d.f. = 3, $P = 0.98$).

DISCUSSION

Our research, as well as other studies (Pasitschniak-Arts and Messier in review, Driver 1987, Jorgenson 1987) show *P. maniculatus, M. pennsylvanicus*, and *C. gapperi* (Order Rodentia, Family Muridae) to be the most common and abundant species of small mammals inhabiting the Canadian prairies. Of the shrews (Order Insectivora, Family Soricidae), *S. cinereus* was the most common, while *S. arcticus* and *Blarina brevicauda* were relatively uncommon. *Eutamias minimus*, the only western chipmunk, was also relatively uncommon. Since Museum Special snap traps were designed to catch mouse and vole-sized mammals, *Thomomys talpoides* was likely an incidental capture. Ground squirrels (Order Rodentia, Family Sciuridae) were found at all treatment sites. *Microtus ochrogaster* and *O. leucogaster* were the two most rare species, and the next important step will be to determine if they are uncommon only in certain habitats, or threatened and in need of protection.

Relative abundance of small mammals was significantly higher in woodland compared to all other habitat types, suggesting that permanent and dense cover of trees and a multi-layered canopy provide an optimal environment for small mammals. Woodland can be considered the most diverse habitat type on the prairies, containing a large variety of plants and invertebrates, which in turn provide a wide assortment of food items for small mammals. In addition, small mammals in woodland habitats likely derive a benefit in terms of cover and protection provided by the trees, shrubs, and diverse ground vegetation. Species richness was higher in woodland, DNC, and native/idle pasture compared to cropland or wetland. The former three habitats provide small mammals with permanent cover and food. In contrast, cropland is a highly disturbed habitat, where the soil is tilled and the crops harvested on a regular basis. During spring, fall, and winter, cropland may have sparse cover, or be totally devoid of vegetation: only summer provides small mammals with cover and potential nesting sites. Similar to cropland, the wetland habitat is also unsettled. Wetlands are often ephemeral and may undergo large fluctuations in water level. Depending on the season and moisture levels, vegetation surrounding these bodies of water may also change from lush, to flooded, to desiccated. Small mammals, such as shrews, which are at home in and around water, will likely be the dominant species in wetland habitats.

Table 3. Median relative abundance, RA, (25, 75 percentiles) and species richness, SR, (25, 75 percentiles) of small mammals in different treatment sites, (1996-1997).

Habitat	RA	SR
Allan Hills	16.6 (15.4, 18.6)	7 (4.7, 7.0)
St. Denis	8.3 (7.3, 11.7)	6 (6.0, 6.2)
Willowbrook	6.1 (4.7, 7.4)	6 (5.5, 7.2)
Baldur	5.1 (4.7, 6.0)	6 (5.7, 6.7)

Relative abundance of small mammals differed among treatment sites. Allan Hills and St. Denis NWA (high treatment sites: >20% mixture of DNC and native/idle grassland), showed significantly higher RA compared to Willowbrook and Baldur (moderate treatment sites: 5% mixture of DNC and native/idle grassland). Species richness, on the other hand, was similar among treatments. These results suggest that while intensive agriculture does not appear to influence species richness, high treatment sites with greater percentage of planted cover and less cropland have a positive impact on small mammal abundance. Thus, management programs involving the restoration of woodlands, native grasslands and conversion of marginal cropland to grass-dominated planted cover are important for small mammal conservation.

CONSERVATION IMPLICATIONS

Habitat loss and fragmentation are occurring throughout the world and are a potential threat to numerous species of wildlife (Wilcove et al. 1986). Currently, our understanding of the role of small mammals in the prairie ecosystem is limited, and the consequences of habitat fragmentation and alteration on small mammal populations remain unclear. Our findings represent much-needed information about the status of small mammals in several human-impacted and fragmented landscapes of the Canadian prairies. This data will serve as an important management tool for: a) small mammal conservation on St. Denis NWA and on other federal lands and reserves; b) future habitat management practices on the prairies (including provincial parks and various habitat restoration programs); and c) recovery plans for rare and uncommon small mammal species, including endangered species that rely on small mammals for food. Currently no reliable material exists on the status of small mammals in most areas of the Canadian prairies, thus emphasizing the fact that further studies of composition and abundance of small mammals are warranted. Furthermore, in view of the importance of small mammals in the prairie ecosystem food web, the complex relationship among small mammals, migratory birds, and predators merits further investigation.

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GENETIC DIVERSITY AMONG FERRUGINOUS AND SWAINSON'S HAWKS: EXPLORING LINKS BETWEEN GENETIC DIVERSITY AND SPECIES CONSERVATION

Jantina S. Portman

Saskatchewan Association for Firearm Education, 1766 McAra Street, Regina, Saskatchewan S4N 6L4

Josef K. Schmutz

Department of Biology, 112 Science Place, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5E2

Abstract: The number of ferruginous hawks (*Buteo regalis*) and their breeding range have declined since prairie settlement by Europeans. While recent stable populations are a positive sign for this hawk's conservation, genetic diversity may have been negatively impacted by hawk population declines and changes in distribution in the past. Loss of genetic diversity may reduce a hawk's chances of persistence in the long-term by increasing the frequencies of harmful alleles or by reducing the genetic capacity of a population to adapt to environmental stresses.

We assessed genetic diversity among ferruginous hawks from seven sites across prairie Canada and from Idaho, U.S.A., using DNA fingerprinting. We also analyzed DNA from Swainson's hawks (*Buteo swainsoni*), a widespread and more numerous prairie hawk. High Average Percent Differences (APD's) in band sharing and heterozygosity estimates from DNA fingerprints indicate a high genetic diversity among sampled populations of both ferruginous and Swainson's hawks. Ferruginous hawk APD and heterozygosity estimates were similar to both Swainson's hawk estimates and to those reported for other bird species with large stable populations. Therefore, current genetic diversity levels are unlikely to hinder the long-term persistence of ferruginous hawks in prairie Canada.

INTRODUCTION

Ferruginous hawks (*Buteo regalis*) have undergone a 50% reduction in breeding range in Canada since European settlement (Schmutz et al. 1990) and hawks may have disappeared entirely from Manitoba during settlement, reappearing in the southwestern corner of the province in the 1970's (Nero and Wrigley 1977). In 1980 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed ferruginous hawks as "threatened" in response to these changes in breeding distribution. Today ferruginous hawks are reestablished in Manitoba and the Canadian range appears to have stabilized at its reduced size. COSEWIC downlisted ferruginous hawks to "vulnerable" in 1995.

A reduction in breeding range alone may not have a large impact on hawk genetic diversity, especially if the remaining population size is still large (Shields 1993). However small hawk populations may become isolated from one another if distribution within the range is scattered. Isolated populations of less than 100 individuals are susceptible to loss of genetic diversity from inbreeding and genetic drift (Shields 1993). Alternatively, the loss of hawks from a region, followed by recolonization with few individuals may produce a small population of hawks with lower diversity than the rest of the population (Slatkin 1987).

The links between species diversity and ecosystem health are inconclusive (Baskin 1994). Species diversity has been shown to increase the ability of plant communities to withstand drought, one aspect of ecosystem function (Tilman and Downing 1994). However species diversity was only beneficial up to a certain point, beyond which increases in numbers of species had no *apparent* measurable effect (Tilman and Downing 1994).

The link from species diversity to genetic diversity is also a controversial issue. Cheetahs (*Acinonyx jubatus jubatus*) are an example of a genetically depauperate species. They have some physical problems attributed to reduced genetic diversity such as low counts of viable sperm, high cub mortality in captive breeding programs and inferior immune response (O'Brien et al. 1985). These characteristics have been cited as evidence for the poor long-term prospects of species survival (O'Brien et al. 1985). Natural history studies of wild cheetahs dispute this interpretation. Studies reveal that cheetahs have "normal" fertility and are adapted to living in low-density populations in open plains (Merola 1994, Caro and Laurenson 1994). Immunity against density-dependent disease outbreaks may have been a low priority in cheetah evolution. Declines in wild populations can be attributed to habitat loss and fragmentation. Captive breeding problems may easily be ascribed to animal husbandry techniques (Merola 1994, Caro and Laurenson 1994). The cheetah controversy illustrates one cost of low genetic diversity – lack of resistance and resilience in the face of change. Species with low genetic diversity are more vulnerable to environmental changes including habitat alteration, unusual weather patterns or disease.

Low genetic diversity can also have detrimental effects in all species through increasing the frequency of detrimental alleles or reducing the genetic capacity of a species to adapt to change (Milton 1993). Inbreeding and loss of genetic diversity have been demonstrated to reduce fertility and production and survival of offspring (Crow and Simmons 1983). In chickens, inbreeding reduces offspring "vigor" measured by reduced weight and age at first egg laying (Haberfeld et al. 1996). In the endangered Florida panther (*Felis concolor coryi*) rapid loss of genetic diversity and increases in harmful allele frequencies have reduced the ability of individuals, and therefore the species, to survive (Hedrick 1995).

In this study of ferruginous and Swainson's hawks (*Buteo swainsoni*) we analyzed genetic diversity using DNA fingerprinting. Ferruginous hawks have undergone changes in population size and distribution over at least the last 100 years which may have resulted in isolation of hawk populations, inbreeding and genetic drift in some regions. Ferruginous hawks exhibit natal and breeding philopatry (Schmutz 1986), possibly increasing their susceptibility to population isolation, genetic drift and inbreeding. Swainson's hawks were not expected to exhibit loss of genetic diversity or subdivision due to their widespread distribution, population size and recorded dispersal abilities (Houston 1990). Thus they served as a useful comparison species for ferruginous hawks. We predicted that ferruginous hawks would have lower genetic diversity and higher subdivision than Swainson's hawks.

METHODS

We selected a total of seven sample sites in Alberta, Manitoba and Saskatchewan and took blood from nestling hawks during yearly banding excursions of local hawk researchers. In some instances, nests were found by opportunistic searching in what appeared to be suitable breeding habitat in the sampling area. We added

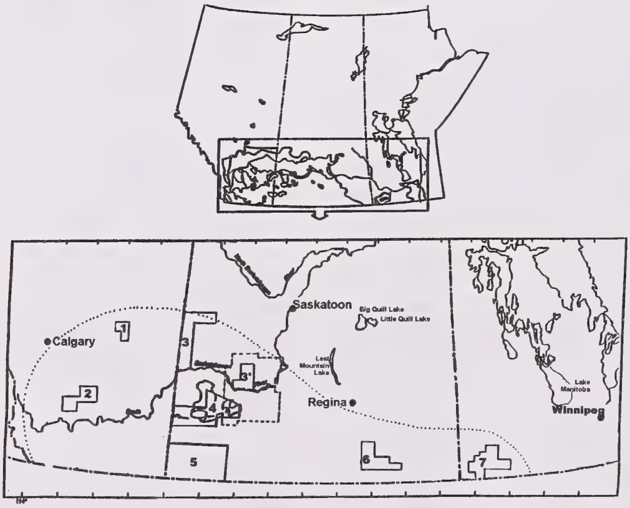

Figure 1. Eight blood collection sites in the Canadian prairies. Ferruginous and Swainson's hawks were sampled from all sites except 3' which was only a Swainson's hawk site. Prairie Ecosystem Sustainability Study (PECOS) research area ——, Ferruginous hawk breeding range ....

another site for Swainson's hawks north of the Saskatchewan River during a banding expedition with C. Stuart Houston. The sites were widely distributed geographically and included both edge and central regions of the ferruginous hawk Canadian breeding range and three habitat types: short grass, mixed grass and sandhill prairies (Figure 1).

We collected blood from 182 ferruginous hawk nestlings in 77 nests between 18 June and 3 July, 1994 and from 10 nests near Hanna, Alberta in 1993. In addition to these Canadian samples, Daniel Gosset provided blood from hawks in Idaho from seven nests in 1991. We sampled 139 Swainson's hawks from 86 nests between 21 July and 9 August, 1994.

We extracted DNA from one hawk per nest and performed Southern analysis (DNA fingerprinting, HAEIII, Jefferys minisatellite probe 33.15) using standard protocols (Petitte et al. 1994, Feinberg and Vogelstein 1983). DNA fingerprint blots were scored for band sharing by visually aligning bands across the gel. A band at 5.6 kb which was present in all of the hawks was used as a reference marker to compensate for differences in DNA migration between lanes. We scored all bands larger than 4 kb with intensities no less than 50% of the darkest band in the lane.

Average per cent difference (APD) in band sharing and genetic subdivision were calculated using the method of Lynch (1990). Hawks were compared within each sample site as well as between sample sites. We estimated heterozygosity among hawks from each region using the method of Jin and Chakraborty (1993). Both APD and heterozygosity can be used as indexes of genetic diversity.

RESULTS

The fingerprint patterns obtained fro Jeffreys probe 33.15 were highly variable for both the ferruginous and Swainson's hawks (Figures 2 and 3). Each individual was "fingerprinted" on between four and seven different blots with excellent reproducibility.

An average of 7.3 bands were scored for ferruginous hawks and 6.8 for Swainson's hawks. A band of 5.6 kb was found in all hawks of both species. In many comparisons, this was the only band which was shared.

Variation Among Ferruginous Hawks

Mean APD's among hawks from each site were consistent from one blot to another s.d.2). APD's ranged from 75 to 80% (Table 1). Between 5 and 10% of similarity in each comparison was due to the band at 5.6 kb

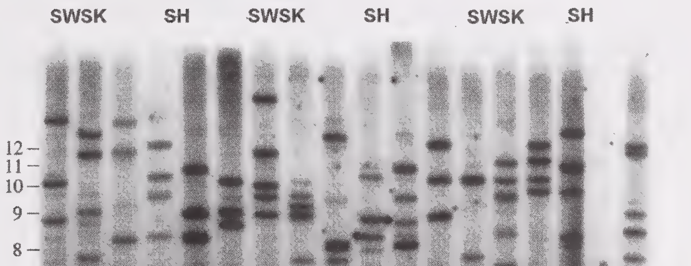

Figure 2. Example of ferruginous hawk DNA fingerprints from SW Saskatchewan (SWSK; lanes 1-3, 7-9, 13-15) and Sandhill (SH; lanes 4-6, 10-12, 16-18). Each lane is from a different hawk. DNA was digested with *HAEIII* and probed with 33.15. The second lane from the right is empty. 1 kb ladder band sizes and migration distances are shown. The 5.6 kb fixed band is indicated with an arrow.

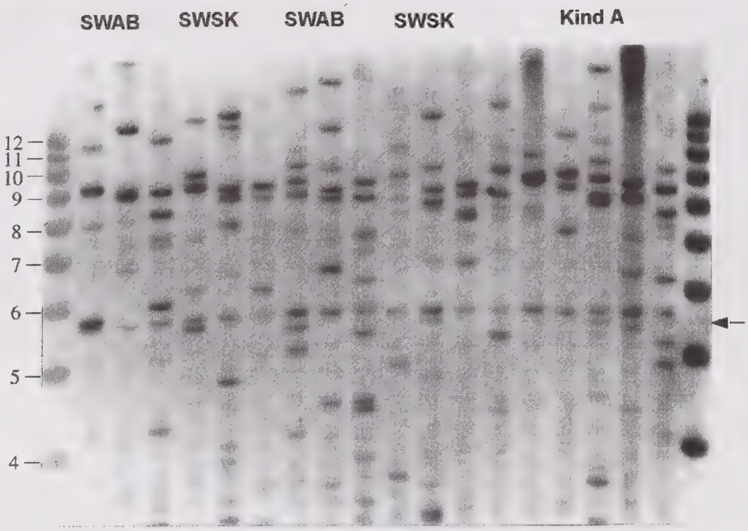

Figure 3. Example of Swainson's hawk DNA fingerprints from SW Alberta (SWAB; lane 1-3, 7-9), SW Saskatchewan (SWSK; lanes 4-6; 10-14) and Kindersley (lanes 15-18). Each lane is from a different hawk. DNA was digested with *HAEIII* and probed with 33-15. The 5-6 kb fixed band is indicated with an arrow.

which is shared among all individuals. Heterozygosity estimates were similar for each site and ranged from 0.71 to 0.74 (Table 2).

Inter-site Variation

We completed 25 of the 28 possible comparisons. Blots comparing Idaho and Sandhill, southeast Saskatchewan (SESK), and Manitoba (MB) were not scorable and there was insufficient Idaho DNA available for re-analysis. The inter-site APD's were very similar to the intra-site APD's and the average was the same (78%; Table 3).

Variation Among Swainson's Hawks

APD's ranged from 76 to 82% (Table 4). Between 5 and 10% of similarity in each hawk-hawk comparison was due to the shared band at 5.6 kb. The analyses were consistent among all blots (s.d.≤3).

Heterozygosity estimates were similar for each site and ranged from 0.70 to 0.74 (Table 5). These values are comparable to ferruginous hawk heterozygosities from the same sites.

Inter-site Variation

We completed twenty-five comparisons. We were unable to produce suitable blots for comparisons

Table 1. Average per cent difference (APD) among ferruginous hawks from each sample site detected by the minisatellite probe 33.15.

Site	# hawks	# blots	Mean APD	S.E
Idaho	7	4	80	5
S.W. Alberta	10	7	75	6
Hanna	10	7	78	4
Kindersley	10	7	78	4
Sandhill	14	6	76	3
S.W. Saskatchewan	13	6	79	3
S.E. Saskatchewan	13	6	78	4
Manitoba	15	6	77	4
Average			**78**	**2**

Table 2. Estimated heterozygosities (H) among ferruginous hawks.

Site	# hawks	# blots	H[1]	s.d.[2]
Idaho	7	4	0.73	0.03
S.W. Alberta	10	7	0.72	0.02
Hanna	10	7	0.73	0.01
Kindersley	10	7	0.72	0.005
Sandhill	14	6	0.74	0.01
S.W. Saskatchewan	13	6	0.71	0.02
S.E. Saskatchewan	13	6	0.72	0.01
Manitoba	15	6	0.73	0.01

[1]Heterozygosity estimated with the method of Jin and Chakraborty (1994)
[2]Standard deviation of n analyses

between Hanna and Kindersley B, Kindersley B and MB and SESK and SH. The APD's were very similar to the intra-site APD's and the average for both was 78% (Table 6). These averages are identical to ferruginous hawk APD's both among hawks from the same sample site and between sample sites.

DISCUSSION

Both ferruginous and Swainson's hawks had a band at 5.6 kb which was present in all individuals. If the fixed band correspond to the same locus within and/or between both species it has probably been maintained in hawks through selection. If this assumption is correct the band violates the requirement for neutral loci in the genetic analysis of Lynch (1990) and Jin and Chakraborty (1994). However, to compare this work with other studies in which both variable and fixes bands were scored, analyses included this 5.6 kb band. This band will decrease APD values so hawk APD's can be considered to be conservative.

APD's can be used as indicators of genetic diversity at the rest of the genome (e.g. O'Brien 1994, Ellengran et al. 1993). Inter-site APD's for ferruginous hawks ranged from 75 ± 3 to 81 ± 3% and Swainson's hawk APD's varied from 75 ± 4 to 81 ± 4% (Tables 3 to 6). These values are similar to those found for outbred palilas (*Loxioides baillevi*) (Jeffreys probe 33.15; APD = 69-74%; Fleischer et al. 1994) and Hispaniolan parrots (*Amazona ventralis*) (Jeffreys probe 33.6; APD = 84%; Brock and White 1992) and larger than the value reported for clapper rails (*Rallus lonirostris*) (Jeffreys probe 33.15; APD = 65%; Fleischer et al. 1995). Intra-site APD's both for ferruginous and Swainson's hawks were also high (Tables 1 and 4) and were comparable to inter-site values. Therefore APD values suggest that genetic diversity is high among all ferruginous and Swainson's hawks sample sites in this study.

Heterozygosity is also referred to as gene diversity (Nei 1987). Intra-site heterozygosity estimates in this study were based on the fingerprint data used to calculate APD's. Therefore it is unsurprising that ferruginous hawks and Swainson's hawks had high intra-site

Table 3. Average per cent difference (APD) between ferruginous hawks from different sites detected by the minisatellite probe 33.15.

	Idaho	SWAB	Hanna	Kind.	SH	SWSK	SESK	MB
Idaho		77	79	80	-	80	-	-
S.W. Alberta			80	78	77	79	79	75
Hanna				81	75	77	80	78
Kindersley					78	78	79	78
Sandhill						77	78	77
S.W. Saskatchewan							79	80
S.E. Saskatchewan								76
Manitoba								
Average		**78**						

All standard errors are ≤3, except Idaho-SWSK (S.E.=4)

Table 4. Average per cent difference (APD) among Swainson's hawks from each sample site detected by the minisatellite probe 33.15.

Site	# hawks	# repeat blots	Ave. APD	S.E
S.W. Alberta	10	7	78	4
Hanna	15	6	77	3
Kindersley A	9	7	82	4
Kindersley B	12	5	79	5
Sandhill	14	6	78	3
S.W. Saskatchewan	12	7	76	4
S.E. Saskatchewan	7	6	77	4
Manitoba	7	6	78	5
Average			**78**	**2**

heterozygosity estimates (0.70 to 0.74; Tables 2 and 5). These values are comparable to numbers reported for outbred clapper rails (*Rallus lonirostris*) using DNA fingerprinting (0.715; Fleischer et al. 1995).

These analyses indicate that despite population declines and range reductions, ferruginous hawks in these sample sites have not undergove recent losses of genetic diversity through inbreeding or population isolation. On the contrary, diversity is high and is comparable to that found in more abundant and evenly distributed Swainson's hawks. There are two likely interpretations: First, ferruginous hawks may not have undergone sufficient declines to leave local populations susceptible to inbreeding and second, local populations have not been isolated from other hawks populations and high genetic diversity has been maintained through immigration.

Extensive modification of the prairie has affected hawks in fertile regions more than those in marginal areas. Hawk numbers in marginal and pasture-rich regions may be large enough to withstand effects of inbreeding and subdivision. In addition, ferruginous hawks may interbreed among the remaining habitats. While both natal and breeding philopatry have been observed in ferruginous hawks (Schmutz 1986, Gosset 1993), dispersal over 250 km has also been reported in this species (Gosset 1993). In this study most sample sites were less than 300 km apart. Therefore interbreeding through a 2-dimensional stepping stone pattern could maintain genetic diversity among hawks. In a stepping stone model, hawks at site 1 disperse to neighboring groups and hawks from those groups disperse to their neighboring groups, some of which will be different from neighbors of site 1. In this way, genes are dispersed among the entire population. Ferruginous hawks have undergone declines in the United States, including extirpation in northeast North Dakota before 1950 and absence from western Montana and northeast Idaho. However, there are still breeding populations in 12 Great Plains states (Bechard and Schmutz 1995) which may also interbreed with hawks in Canada.

Since APD's were so high among hawks from the Canadian sample sites, it is not surprising that comparisons with Idaho hawks yielded similar APD's. APD's are maximized at the outbred level.

Table 5. Estimated heterozygosities (H) among Swainson's hawks from each site.

Site	# hawks	# blots (n)	H[1]	s.d.[2]
S.W. Alberta	10	5	0.74	0.03
Hanna	15	5	0.7	0.03
Kindersley A	9	5	0.74	0.03
Kindersley B	12	5	0.71	0.02
Sandhill	14	5	0.73	0.01
S.W. Saskatchewan	12	7	0.71	0.03
S.E. Saskatchewan	7	6	0.7	0.04
Manitoba	7	6	0.71	0.05

[1]Heterozygosity estimated with the method of Jin and Chakraborty (1994)

[2]Standard deviation of n analyses

Table 6. Average per cent (APD) between Swainson's hawks from different sites detected by them minisatellite probe 33.15.

	SWAB	Hanna	Kind. A	Kind. B	SH	SWSK	SESK	MB
S.W. Alberta		79	79	76	79	81	76	78
Hanna			78	-	77	76	75	79
Kindersley A				79	79	80	78	79
Kindersley B					80	77	78	-
Sandhill						78	-	78
S.W. Saskatchewan							77	77
S.E. Saskatchewan								75
Manitoba								
Average		**78**						

All standard errors are ≤3, except Idaho-SWSK (S.E.=4)

CONCLUSIONS

Contrary to our predictions, ferruginous hawks sampled in this study did not have less genetic diversity than Swainson's hawks as assessed by Jeffreys 33.15 DNA fingerprints.

The prospects of ferruginous and Swainson's hawks in Canada are positive. Swainson's hawks have high genetic diversity and no signs of genetic subdivision. Ferruginous hawk distribution has stabilized (Schmutz et al. 1990) and changes in distribution of ferruginous hawks over the last one hundred years have apparently not impacted genetic diversity. Dispersal and interbreeding among hawks, which may have contributed to the high APD's, may continue to prevent loss of genetic diversity among ferruginous hawks.

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RESTORATION ECOLOGY

RESTORATION AND REVEGETATION: DOES GRASS MAKE A PRAIRIE?

Scott D. Wilson and Janice M. Christian

Department of Biology, University of Regina, Regina, Saskatchewan, S4S 0A2

Abstract: Ecosystem restoration could ideally address several components such as soils, decomposers, and plants. Revegetation, in contrast, involves only plants, and, typically, few species. The impacts of single-species plantings on ecosystem function have received little attention. We examined five fields abandoned for 50 years that had undergone succession to native grasses, and five that were planted with an introduced species, crested wheatgrass. Crested wheatgrass fields contained few native species, resulting in significantly lower species richness and diversity. Plants most similar to crested wheatgrass, such as native cool-season grasses, were most likely to be excluded. Soils under crested wheatgrass had significantly lower moisture, available N, total N and total C than soils under successional prairie. Crested wheatgrass fields had significantly higher shoot mass which presumably increased evapotranspiration and lowered soil moisture. Root: shoot ratios under crested wheatgrass were less than half those under successional prairie, because root mass was significantly higher under native grasses. Thus, the biomass allocation pattern of a revegetation species had large effects on ecosystem function. In contrast to crested wheatgrass, successional prairie was similar to native prairie for most of the attributes measured. Ecosystem restorations should include diverse mixes of native species.

Revegetation with a single species often displaces other species and reduces diversity. Less obvious effects include the alteration of ecosystem function, including the size of nutrient and energy pools. Even subtle differences between diverse communities and monocultures, such as in root allocation, could influence pool size.

Crested wheatgrass (*Agropyron cristatum*), an introduced perennial tussock grass, has been planted on the northern Great Plains since the 1930s and dominates 6 - 10 x 10^6 ha (Lesica and DeLuca 1996). We expected this grass to alter soil C for several reasons. First, *A. cristatum* stands are stable and exclude native species for decades (Looman and Heinrichs 1973). Second, its low root: shoot ratio (Dormaar et al. 1995) should result in relatively low contributions to soil organic matter. Third, the tissue of introduced grasses is typically N-rich relative to native grasses (Wedin and Tilman 1996), which could enhance litter decomposition and lower organic matter accumulation. Lastly, comparisons of undisturbed prairie and *A. cristatum* stands show significantly less organic matter under *A. cristatum* (Dormaar et al. 1995). This difference, however, could result because *A. cristatum* was planted on disturbed soil that had already lost organic matter during cultivation. We avoided this problem by comparing soil under *A. cristatum* with soil in fields that had also been abandoned from cultivation but had undergone natural succession and are currently dominated by native prairie plants. Undisturbed prairie was also studied for comparison.

We sampled a 200 km^2 area in Grasslands National Park (49° 22' N, 107° 53' W) near the Montana-Saskatchewan border. We selected five stands in each of undisturbed prairie, successional prairie (abandoned cropland that had been allowed to undergo natural succession), and abandoned cropland planted with *A. cristatum*. All successional prairie and *A. cristatum* stands had been cultivated and then abandoned for at least 40 years, allowing us to examine sites with similar disturbance histories. Stands were interspersed (Christian 1996). We examined species composition, diversity, root and shoot mass, and soil (total C and N, available N and moisture). Ten plots were randomly located in a 30 x 30 m area in each stand. In each plot, species cover was measured in a 50 x 100 cm quadrat using Daubenmire's scale, in August of 1995. Diversity was calculated from cover data. Shoot mass was collected from a 10 x 100 cm quadrat in June and August, dried and weighed. At the same time, root mass was collected in three cores (2 cm diameter, 10 cm deep); cores were combined, washed, dried and weighed. Three other cores were collected in June, August and October. Cores for each date were combined and divided into two portions, one for N analysis and one for gravimetric soil moisture determination. Soil for available N analysis was extracted in 0.02 M KCl; solutions were decanted and frozen until analysis for the total amount of ammonium and nitrate (available N) using an ion-selective electrode. Three other cores were collected in August, combined and analyzed for total C and N using an ANCA-GSL sample preparation unit on a mass spectrometer. Only data from the last sample period for each variable are reported; all variables showed similar trends across all sample periods. Data were analyzed with nested ANOVAs.

Undisturbed prairie and successional prairie were similar in species composition and diversity, although total cover was slightly lower in the successional stands. In contrast, stands planted with *A. cristatum* remained dominated by this species. The only common native species in *A. cristatum* stands was the spikemoss *Selaginella densa*. Native grasses which shared the C_3 photosynthetic pathway with *A. cristatum* (*Koeleria pyramidata* and *Stipa comata*) were absent; the only grass that commonly occurred with *A. cristatum* was *Bouteloua gracilis*, which has a C_4 pathway. Diversity was significantly lower in *A. cristatum* stands.

Total soil C was almost identical in undisturbed and successional prairie, suggesting that soil organic matter lost during cultivation had been replaced during 40 years of succession by native species. In contrast, total soil C under *A. cristatum* was about 25% lower than in undisturbed or successional prairie, as was total soil N. Thus, soil organic matter recovery was significantly less under the introduced grass than under native grasses.

A. cristatum fields and successional prairie also differed in short-term resource availability. Soil available N (sum of ammonium and nitrate) did not vary significantly between undisturbed prairie and successional prairie, but was significantly lower in *A. cristatum* stands. Similarly, soil moisture was significantly lower under *A. cristatum* than in undisturbed or successional prairie, as occurred in Wyoming (Trlica and Biondini 1990). Taken together, the results indicate that soil recovers the characteristics of undisturbed prairie during succession under native grasses, whereas soils under *A. cristatum* remain low in organic matter, N and water.

Differences in soil characteristics between native grasses and *A. cristatum* may be caused by differences in biomass allocation. Shoot mass did not vary significantly between undisturbed and successional prairie, but was about twice as high in *A. cristatum* stands, which is why this species is widely planted. Root mass, however, was significantly lower in *A. cristatum* stands than in successional prairie. As a result, the root: shoot ratio of *A. cristatum* stands was only a quarter that of undisturbed prairie or successional prairie. The data suggest that soil C and N are lower under *A. cristatum* because it allocates less mass to roots, in accordance with positive correlations between prairie root production and soil organic matter.

Agropyron cristatum may also affect soil organic matter through its impact on water availability. The high shoot mass of *A. cristatum* stands may increase evaporative demand and reduce soil moisture. This could retard productivity and the long-term accumulation of organic matter. Low soil moisture also slows mineralization, decreases available N, and could further reduce productivity and organic matter accumulation.

Prairie soils have among the highest soil C storage of all terrestrial ecosystems on a per-square meter basis (Schlesinger 1991). Because soil under *A. cristatum* has about 25% less C than soils under successional prairie, and temperate grassland soils contain an average of 19.2 kg C/m^2 (Schlesinger 1991), we calculated the contribution of *A. cristatum* to atmospheric C as 25% of this multiplied by 10 x 10^6 ha dominated by *A. cristatum*. This suggests that planting *A. cristatum* may have left about 5 x 10^8 t of C in the atmosphere that would otherwise occur as soil organic matter. Disturbed prairie soils might be more effective C sinks if diverse mixtures of native grasses were used for revegetation.

In summary, the use of a single species for revegetation produced grasslands that differed from native prairie not only in species composition, but in ecosystem function as well.

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PRACTICAL ASPECTS OF USING FIRE AND GLYPHOSATE TO ERADICATE SMOOTH BROME (*BROMUS INERMIS*) IN A SAND HILLS GRASSLAND

Luc Delanoy

Meewasin Valley Authority, 402 3rd Avenue South, Saskatoon, Saskatchewan S7K 3G5

Abstract: Weed control has become an important aspect of Meewasin Valley Authority's natural area management program. Experiences in controlling Smooth brome and other weeds at a 69 ha sand hills grassland over a five-year period are highlighted. The main management techniques used were chemical and/or prescribed burning. Glyphosate was either wicked or sprayed and used either alone or in combination with early spring burning. Observations are based on treating 284 Smooth Brome patches each measuring 100 square meters or less and edges of larger patches totaling roughly 5,000 lineal meters.

The desire to reduce or eliminate the use of chemicals and the inappropriateness of other vegetation management techniques at this site has led to experimentation with fire alone. Literature indicates potential benefits using fire in early spring, late spring and fall periods. Meewasin intends to test fire during these time periods and over a wide range of vegetation types. We anticipate other benefits from fire including increased biodiversity and restoring the historical balance between grassland and woodland. The use of fire raises issues of efficiency and safety. Streamlining the construction of fireguards is critical as this is a laborious process and represents the greatest risk of accident. Some thoughts on achieving this are presented.

BACKGROUND

"Invasive plants have recently gained notoriety as major conservation and management concerns in natural ecosystems" (Hobbs and Huenneke 1992). Natural prairie remnants in the Saskatoon region are showing signs of exotic plant invasion. Detailed vegetation inventories from two local prairies indicate a substantial percentage of exotic plant species in the vicinity of Saskatoon. Seventeen percent of the vascular flora at Saskatoon Natural Grasslands and 9% at nearby riverbank lands are non-native (Thorpe and Godwin 1994). Exotic plants at Cranberry Flats (C.F.), a 69 ha sand hills grassland, are mostly associated with past disturbances including grazing, cultivation and recreation. They continue to expand even though recreation has been the only activity since the 1960's. These changes are not well understood by the general public. Most site visitors are not able to distinguish native plant communities from those altered by invasive exotics. Restoration activities attract attention and provide field opportunities to explain management issues.

Despite the numerous introduced species, only a few have become invasive. The most problematic are Kentucky blue grass (*Poa pratensis*), smooth brome (*Bromus inermis*), quack grass (*Agropyron repens*), crested wheatgrass (*Agropyron pectiniforme*), alfalfa (*Medicago sativa*) and sweet-clover (*Melilotus sp.*) All are cool season plants.

Smooth brome and Kentucky blue grass are common in moist positions of remnant prairies in the vicinity of Saskatoon. Growth rates of smooth brome were measured at 8 sites over a one-year period on sandy loam soil at Wanuskewin Heritage Park (W.H.P.) and at 1 site over an eight-year period at Beaver Creek Conservation Area (B.C.C.A.). Smooth brome spread from the leading edge on average 27 cm per year at W.H.P. and 17 cm per year at B.C.C.A. Smooth brome annual growth rates are estimated at 7% at C.F. and 12% at B.C.C.A.

While Meewasin is actively pursuing the control of exotic plants and in particular smooth brome, it is impractical to remove all exotics from the valley. With this in mind Meewasin is targeting specific problem species in the best quality natural areas. The goal is to conserve a cross section of the best representative habitats. Prairies are currently given priority over moister valley landscapes because of their relative stability, rareness and ease of management. Weichel estimates that less than 2% of upland habitats near Saskatoon remain in natural condition (Weichel 1992).

INVENTORY

A detailed inventory of smooth brome patches was completed for Cranberry Flats. Locations were field mapped on air photos and later transferred to a Geographical Information System. Field identification is relatively easy in March or April when the tall golden leafy stems contrast with the shorter, snow covered prairie grasses and the taller leafless shrubs. Smooth brome spreads by rhizomes and tends to form circular patches with distinct edges.

Management histories and key attributes for 322 stands are compiled in a database. Key attributes are used to rank each stand for eradication. Highest priority is given to small stands surrounded by native grassland as these islands are relatively easy to control, usually reverting to prairie on their own. Left uncontrolled, their high edge-to-area ratios result in rapid spread.

WEED CONTROL TECHNIQUES

General

Of the 322 patches, 300 measure less than 100 square meters each. To date 284 have been wicked or sprayed with Roundup. Based on data from 164 eradicated brome stands, the average time to control brome stands measuring less than 100 square meters is 3 years. This time frame is conservative as it includes considerable experimentation. Following the recommendations in this report will reduce the 3-year time frame.

The 22 larger stands have been edge treated with Roundup to halt their spread. Edges measure about 5000 meters in length. Early detection and control are important because compound growth rates estimated at 7% for C.F. will result in smooth brome doubling in 10 years.

Over time it is anticipated that the length of "edge" needing treatment will diminish as man-made and natural ecological barriers are used to advantage. These include trails and roads as well as thick brush or dune soils. This treatment will not eliminate seed production or reduce plant vigour in the stand interiors. Stopping seed production is an important aspect as several new stands have established from seed in the past five years.

Techniques resulting in slow, subtle positive change are favoured for large sites which cover about 11 ha or 17% of the site. This effectively eliminates revegetation costs associated with more intrusive methods such as chemical or ploughing. Grazing, mowing and fire were considered in choosing a management technique.

Grazing is widely used but is not appropriate at Cranberry Flats as it would conflict with the passive recreational use encouraged there. There is evidence that grazing can encourage the spread of Kentucky blue grass, an undesirable common plant. A North Dakota grassland described by Hoffman and Ries (1989) showed 26% cover of Kentucky blue grass in grazed areas and only 11% in ungrazed areas. Mowing is not generally thought to produce the diversity associated with grazing (Van den Bos and Bakker1990). As well, mowing does not fit with the natural ambience encouraged at Cranberry Flats.

Fire is a natural process which increases diversity in plants and wildlife when used at intermediate frequencies (Hobbs and Huennecke 1992). Anecdotal evidence indicates an increase of woody plants at Cranberry Flats following settlement. Fire can help restore the historical balance between woodland and prairie at Cranberry Flats. It is a proven method for suppressing woody species (Launchbaugh 1972, Wright and Bailey 1982). Repeated annual burns during the appropriate season can favor native species over cool season exotics.

Chemical

Glyphosate was either wicked or sprayed and used either alone or in combination with early spring burning. Early spring burning followed by moist conditions strongly favors the growth of smooth brome (Willson and Stubbendieck 1997). The resulting leafy growth improves the uptake of glyphosate. In contrast, spraying in the fall or in sod bound or drought stressed grass was not successful.

Spraying is preferred over wicking as it provides labor savings, reduced chemical use and is practical in grassland or woodland. Spraying a 1% solution onto vigorously growing plants in spring or early summer has proven most successful. A quad mounted 60 liter tank with spray wand was used for grasslands while a 15 liter backpack unit was used in woodland.

Wicking with a 33% solution is recommended. Grilz (1992) found this technique effective when applied during tiller elongation following an early spring burn. Wicking has the advantage of removing taller exotics without affecting shorter native plants. Wicking is particularly effective following an early spring burn which increases this height differential or where smooth brome is intermixed with very low species such as low sedge (*Carex eleocharis*) or blue grama (*Bouteloua gracilis*). This condition appears to occur where overgrazing or cultivation is discontinued. Meewasin uses a 3 meter wide sponge applicator mounted on a steel frame and bicycle wheels. This is suitable for prairie sites but not wooded areas. A very small "hockey stick" applicator was also used early in the program but is only practical where weed density is light.

The advantage of wicking over spraying is marginal in many cases as native plants are often missing. This is especially true in stand interiors. As well, some native plants are resistant to glyphosate. These include creeping juniper (*Juniperus horizontalis*), common horsetail (*Equisetum arvense*) and lance-leaved psoralea (*Psoralea lanceolata*), all fairly common in sand hills prairie. Low growing native plants are also sometimes spared from the spray when growing in heavy tall smooth brome stands.

The program was experimental and conservatively applied in the beginning for fear of damaging native plants where they intermixed with bromegrass. Disturbances also increase the chance of weed invasion. The program is now applied more aggressively with the knowledge that establishment by native plants is practical and efficient when closely monitored to detect and remove weeds as they appear.

In hindsight it appears better to sacrifice some native material rather than underspray. Underspraying results in poor control and the need to spend more resources on the same patch rather than moving on to new patches where diameters are increasing at a rate of 0.35 meters per year. Aggressively spraying removes most plant material but it is still inevitable that brome stems will be missed. Missed stems with bare ground around them grow rapidly and are easily controlled the following year as the robust growth is easy to detect and responds well to chemical control. Rogueing is more practical at this stage due to the bare soil conditions. A coloring agent in the chemical would improve coverage.

Considerable time was wasted in spot spraying areas where weak smooth brome expansion into the grassland resulted in a diffuse mix of smooth brome and native species of even height. Wicking would be a better option if fire successfully lengthens smooth brome. Where this is not achievable it would be more efficient to use fire or other drying techniques to stress the brome grass. Seeding or hay mulching in poorly prepared sites often results in similar conditions. Weed control prior to seeding is an excellent investment. Two seasons of weed control prior to planting is ideal. Importing topsoil is costly and caused a noticeable increase in weed growth at Cranberry Flats.

Fire

Burning causes a loss of nitrogen from the prairie ecosystem (Redmann et al. 1993) and reduces moisture availability. These conditions put Kentucky blue grass and smooth brome at a competitive disadvantage. Kentucky blue grass was noted to decline in many areas during the drought of the 1930's (Weaver 1954). Repeated annual burning likely accentuates the effect.

Seasonal timing is an important variable determining fire's effects. Repeated early spring burns have shown reduced cover and vigour for smooth brome (Becker 1989, Anderson and Bailey 1980). A single spring burn in fescue grassland in Alberta reduced the cover of rough fescue (*Festuca altaica*), while western porcupine grass (*Stipa curtiseta*), which grows a little later, was less affected (Bailey and Anderson 1978). Kentucky blue grass also greens early. Carefully timed spring burning could possibly discriminate against it to the advantage of later growing cool and warm season native plants.

Late spring burning coincides with tiller elongation of smooth brome and sets it back more than burning during other growing stages (Willson and Stubbendieck 1997). During tiller elongation there are low root carbohydrate reserves and poorly developed basal buds (Paulsen and Smith 1968). In tallgrass prairie late spring burning is commonly used to benefit the large component of warm season grasses. This could have application in sand hills grassland which has a higher percentage of warm season plants than mixed or fescue grassland. Repeated annual spring burning over many years was shown to increase sand reed grass (*Calamovilfa longifolia*) at the expense of cool season grasses in Wainwright, Alberta (Anderson and Bailey 1980).

Fall burning has a greater negative impact on production compared to spring burning. Reduced snow trapping is possibly one cause. Again, species requiring more moisture will likely be placed at a greater disadvantage under this scenario. Meewasin is beginning treatment of the larger exotic grass stands with early spring, late spring and fall timings, annually and over a long period of time with the expectation of reduced vigor of cool season exotics and woody species and an increase of warm season native plants.

Constraints to burning are mostly associated with fireguard construction. It is an unrewarding and physically demanding task and represents the greatest risk of fire escape. Techniques to minimise the need for or construction of fireguards should be utilised. For example, snow can be a useful medium. Snow fencing can be used to strategically place snowbanks. Some sites have natural or man made firebreaks and these should be used to full advantage. Leaf blowers are useful aids (Stubbendieck et al. 1996) and propane torches could be used to burn in guards when grassland is not able to burn on its own. Burning with propane or similar fuel would substantially reduce manpower and equipment requirements. Carefully monitoring weather conditions and providing a mobile water source would minimise chances of wildfire. Small patches could be entirely burned this way.

REVEGETATION

Most stands have grown back with native species with minimal effort. On occasion weeds established with Canada thistle (*Cirsium arvense*) and perennial sow-thistle (*Sonchus arvensis*), alfalfa and sweet-clover the main species of concern. Open patches void of growth persist during the first year followed by native and exotic annuals establishing the following year. Within 2-3 years native perennials begin to show. Pasture sage (*Artemisia frigida*) and prairie sage (*Artemisia ludoviciana*) are particularly successful at establishing. Beautiful sunflower (*Helianthus laetiflorus var subrhomboideus*), is also fairly successful. It is a showy wildflower which can be used to create colourful patches that help beautify the landscape while reclaiming it. Yarrow is another fast spreading and showy wildflower and was successfully and efficiently divided and replanted in the fall. Wildflowers can be expected to perform well for several years before the site reverts to a grass cover.

Costs of revegetation vary considerably. Meewasin's costs to transplant 0.4 ha of prairie sod averaging a depth of 15 cm was $25,000 per ha while tall grass prairie in Winnipeg with a depth of 25 cm was moved at a cost of $120,000 per ha (Doug Clark Pers. Comm.). Meewasin hay mulched 2.3 ha at Cranberry Flats and B.C.C.A. for approximately $400 per ha. Meewasin has seeded a mix of 4 native grass cultivars for approximately $300 per ha. Some ecologists do not advocate using commercial seed as these tend to be cultivars of native seed bred for vigor and uniformity but without the broad, local gene pool. Hay mulching appears to be the most practical method.

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AN ECOLOGICAL APPROACH TO SEED MIX DESIGN AND NATIVE PRAIRIE REVEGETATION

Andy Hammermeister

Site 601, Box 28, RR6, Saskatoon, Saskatchewan S7K 3J9

Anne Naeth

Department of Renewable Resources, University of Alberta, Edmonton, Alberta T6G 2H1

Abstract: Oil and gas development in southeastern Alberta is further threatening an already endangered native prairie ecosystem. Although native plant species are being used for revegetation of wellsite disturbances on native prairie, current seed mixes have low diversity, consisting primarily of relatively competitive wheatgrass cultivars. Prairie conservationists are concerned that the current revegetation practices may eventually degrade the integrity and diversity of native prairie.

The Native Prairie Revegetation Research Project was jointly initiated in 1995-96 by individuals in industry, government, and academia who recognized the need for improved methods of native prairie revegetation. The objectives of this research include the evaluation of alternative revegetation methods to achieve a greater understanding of diversity and its relationship with ecosystem function. This knowledge will be used by government and industry to more effectively rehabilitate wellsite disturbances. The cost, practicality, and success of selected revegetation treatments were of specific interest to industry.

The research is being conducted on abandoned wellsites in the Dry Mixed Grass Natural Subregion of Alberta. Five treatments have been applied at each wellsite: natural recovery (not seeded), current seed mix (low diversity, wheatgrass dominated mix), simple seed mix (five dominant grass species on Dry Mixed Grass prairie), diverse seed mix (nine grasses and 13 forbs), and an undisturbed control. Success of rehabilitation will largely be determined by the degree of similarity to undisturbed prairie which the treatments have reached over three growing seasons. Interim results will be presented.

INTRODUCTION

The Native Prairie Revegetation Research Project is a joint initiative involving industry, government, and academia. In addition to investigating various methods of native prairie rehabilitation, this research was intended to investigate the problem of seed mix design. Native seed mix composition is frequently restricted by limited supply, high cost, handling problems, and low or slow establishment rates. Although these are important factors dictating day-to-day rehabilitation practices, they will not be discussed in this paper. These, to a great extent, are technological constraints. The purpose of this paper is to address the importance of goals in planning rehabilitation practices and linking them through ecological considerations to seed mix design.

A FOUR STEP PLANNING PROCESS

Connecting management objectives with functional attributes of ecosystems can be viewed as a four step process which involves the identification of: (a) management objectives, (b) factors which regulate or determine the nature of the ecosystem, (c) desired functional and structural attributes of the ecosystem which will fulfill the management objectives, and (d) plant species/communities which conform with the previously listed desired attributes.

Step 1: Setting Goals

The term rehabilitation "Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values" (Powter 1994). This term is preferred since it encompasses not only land use and capability, but also ecosystem stability and sustainability, environmental degradation, and aesthetic values which are not clearly included in the definitions of reclamation or revegetation (Powter 1994). As such the goal of rehabilitation forms the basis of the goals which we have outlined for Dry Mixed Grass Prairie in Table 1. Management objectives should include societal values and the services which the ecosystem is expected to provide while considering its inherent properties. These values may include conserving the inherent beauty and diversity of native prairie in addition to its productivity. Some objectives may not be fully compatible and priorities may need to be set.

Step 2: Factors Controlling Ecosystem Properties

Every ecosystem is controlled by specific factors which determines its function and species composition.

Identification of the critical processes which regulate or determine the nature of the ecosystem in question is the next step toward linking management objectives with seed mix composition. Ultimately, the plant community which establishes must be well adapted to these controlling factors to fulfill the management objectives. For Dry Mixed Grass prairie, these have been divided into primary processes, those which ultimately determined the nature of the ecosystem present, and secondary processes, which limit resource availability or community characteristics (Table 1). Fire, grazing, and drought are considered to be the primary factors producing the inherent characteristics of grassland ecosystems (Sala et al. 1996).

Secondary factors such as nutrient cycling may influence the overall ability of the system to fulfill objectives within the limitations of the primary factors. For example, organic matter decomposition progresses at a relatively slow rate under dry and seasonally cool conditions. Availability of nutrients, especially nitrogen, is henceforth limited for plant growth and therefore restricts the maximum potential for sustainable forage production. Invasion and dominance of exotic species may result in less diverse ecosystems, impair species conservation efforts, and/or alter ecosystem function (Romo and Grilz 1990). Soil properties (e.g. texture, structure, water holding capacity) may also influence resource capture and accessibility (Reynolds et al. 1997).

Many of the factors may be managed to promote desirable ecosystem characteristics. However, the net benefit of these management practices may be goal specific. For example, fire may be needed to sustain ecological diversity. However, burning may also result in a temporary loss of forage, wildlife habitat, and carbon while also reducing resource use efficiency. Although fire may temporarily limit the effectiveness of the ecosystem in meeting some objectives, it may increase this effectiveness over the long term. Similarly adding fertilizer to reduce nutrient limitations may increase productivity but may also decrease community diversity or change community composition. Removal of grazing during early stages of plant community development will reduce stress on most plants and result in a healthier plant community which establishes and provides ground cover more rapidly. Appropriate long term grazing management will be more likely to result in a highly productive, stable, and self-sustaining plant community.

Step 3: Identifying Desirable Ecosystem Attributes

Most of the management objectives listed in Step 1 (Table 1) are related to functional attributes of ecosystems, processes which involve the capture and use of resources. However, habitat for wildlife, species conservation, and biodiversity are predominantly related to the structure or composition of the plant community. These community characteristics cannot be sustained unless they are compatible with ecosystem function. Therefore we must first identify the nature of the processes which are most critical for meeting our management objectives within the boundaries of the controlling factors.

For Dry Mixed Grass prairie, the functional attributes have been separated into universal functions and endogenous properties resulting from universal function (Woodward 1993) (Table 1). The desirable universal function attributes address the efficient capture and use of resources. Many of the services provided by an ecosystem are directly associated with resource use efficiency. Examples would include productivity and ecosystem stability. Most of the universal function attributes listed in Table 1 are consistent with a late successional ecosystem with the exception of high productivity (Odum 1969). Most highly productive ecosystems are associated with frequent disturbance and an abundant supply of resources. In this case our objective is to maximize productivity of a late successional community.

The universal functions have been designed to meet both the management objectives and consider the controlling factors. The universal functions emphasize efficient capture and use of resources since some of them (i.e. water and nitrogen) are limited in supply. Conversely, loss of these resources not only reduces the

Table 1. Linking management objectives with ecological attributes of ecosystems.

Step 1. Management Objectives/Services of Dry Mixed Grass Native Prairie

1. Prevention of ecological degradation (erosion, organic matter loss, nutrient loss)
2. Sustainability in forage production and quality
3. Multiple land use (grazing, wildlife, recreation)
4. Sustaining diverse ecosystems
5. Conservation of rare species and genetic pool
6. Efficient capture, use, and conservation of resources
7. Carbon sink

Step 2. Factors Controlling Ecosystem Structure and Function

Primary

8. Low precipitation:evaporation ratio, periodic drought (climate)
9. Fire
10. Grazing

Secondary

11. Nutrient turnover (mineralization, immobilization)
12. Invasion of exotic species
13. Historical soil development

Step 3. Ecosystem Attributes Fulfilling Goals/Services

Universal Functions	Associated Structural/Compositional Attributes
1. Efficient energy capture and use (photosynthesis, respiration) 2. Efficient water capture, use, and conservation 3. Efficient nutrient capture, use, and conservation 4. Maximize C fixation and retention, photosynthesis:respiration ratio – 1:1	1. Diverse physiological adaptations (cool season plants (C_3), warm season plants (C_4), crassulacean acid metabolism (e.g. cactus)) 2. Structural diversity 3. High canopy and ground cover 4. Diverse phenology (varying species adapted to growing at different times of the year) 5. Diverse rooting strategies, high root density 6. Diversity in number and composition of functional groups
Endogenous Properties Accruing From Function	
1. Stability, dynamic equilibrium	1. Species diversity, functional group diversity 2. Diverse rooting and resource capture strategies 3. Diverse reproductive strategies 4. Presence of disturbance tolerant species
2. Occasional fire	1. Litter build-up
3. Exclusion of invading species	1. Minimize bare ground 2. Broad range and efficient resource niche utilization
4. High forage supply	1. Diverse supply of forage in terms of quality, quantity, and seasonal availability 2. Diverse phenology 3. Stress tolerance (e.g. drought and grazing)

stability and productivity of the ecosystem, but may also result in ecosystem degradation (e.g. erosion, groundwater contamination).

Efficiency of resource capture and utilization has considerable influence on endogenous properties such as stability and sustainability. Fire, partly related to litter build up, productivity, and resource capture, is a desirable process for species conservation and diversity promotion. Invasion of non-native species is also retarded through efficient capture of resources by minimizing bare ground and competitive exclusion). High forage supply and/or productivity also results from efficient capture and use of resources. A diverse supply of forage will sustain multiple species use and promote grazing, one of the primary processes influencing grassland condition.

Plant community structural/compositional attributes consistent with the functional attributes are also listed in Table 1. Several of these attributes refer to diversity in species composition and associated characteristics such as: phenology (timing of growth), physiological adaptations to various forms of stress and in efficiency of resource capture, growth habit, and rooting habit. From this process it becomes evident that high diversity is desirable. The nature and extent of diversity that is necessary to produce the listed functional attributes is of current debate in the literature (e.g. Sala et al. 1996, Tilman et al. 1997, Grime 1997, Hooper and Vitousek 1997, Lawton and Brown 1993, Walker 1992, Wardle et al. 1997). However, since our management objectives include sustaining diverse ecosystems, providing habitat for wildlife, and conserving genetic resources, some degree of diversity will certainly be necessary.

Step 4: Seed Mix Determination

From Step 3 we have determined the structural and compositional attributes of an ecosystem which are consistent with meeting management objectives. Now we must determine what species are best suited to providing these attributes. The species selected must be consistent with inherent soil properties such as texture and drainage for the site in question. Examples may include western wheatgrass (*Agropyron smithii* Rydb.) which is a cool season plant, establishes quickly, provides good ground cover, is deep rooted, and reasonably productive. Blue grama grass (*Bouteloua gracilis* Lag.) is a warm season plant which is well adapted to heavy grazing pressure and drought and will promote organic carbon buildup due to its low shoot:root ratio, but is relatively low in productivity. By increasing structural diversity and food supply, forbs and shrubs improve habitat for insects and wildlife. Leguminous forbs provide the added benefit of fixing atmospheric nitrogen. It becomes apparent that no single species will effectively meet all of the management objectives. A well planned seed mix with sufficient diversity will prevent environmental degradation in the short term while accelerating the long term process of community succession.

INTRODUCING THE NATIVE PRAIRIE REVEGETATION RESEARCH PROJECT

Unfortunately, we have a limited understanding of the long term influence of various rehabilitation practices on successional processes following disturbance. To develop a complementary seed mix, we need to understand how individual species will respond in a community.

Currently, most industry contractors use relatively aggressive cultivars of native species which have high availability, relatively low cost, and a high and rapid rate of establishment. These plant characteristics allow the revegetation contractors to meet Alberta's wellsite reclamation criteria (Alberta Environmental Protection 1995) in a timely and cost effective manner. However, the aforementioned practices may reduce genetic diversity, introduce invasive non-native species, and produce a community too competitive to allow the native plants surrounding the wellsite to invade and establish a diverse community. The question then becomes: What rehabilitation practices should be employed which fulfill the management objectives set forth in Table 1? The Native Prairie Revegetation Research Project was initiated in 1996 to address this question.

We have established research plots on seven drilled and abandoned, non-producing wellsites in the Brooks-Bow Island-Medicine Hat area. At each wellsite five treatments have been implemented (Table 2). Species composition of seed mixes (Table 3) were selected based on the treatment strategy (Table 2) and typical composition of Dry Mixed Grass prairie (Gerling 1996, Nernberg 1995).

Through a number of vegetation and soil observations/measurements, we intend to determine which treatment will most effectively "ensure that the wellsite will be returned to a relatively stable and self-sustaining native prairie condition without the use of introduced/non-native plant species and without further environmental degradation".

Table 2. Description of treatments in the dry mixed grass portion of the native prairie revegetation research project.

Treatment	Description
Natural Recovery	no seeding - natural prairie recovery
Current	low diversity mix consisting primarily of competitive native wheatgrass species
Simple	simple native grass mix consisting of species dominant in undisturbed prairie
Diverse	diverse seed mix of native grasses and forbs
Control	undisturbed control to which the treatments will be compared

SUMMARY

In native prairie rehabilitation the importance of linking goals with ecological attributes of plants and ecosystems is often overlooked due to practical restrictions such as seed availability, cost, and time constraints. We must remember that short term success of rapidly establishing, highly productive seed mixes may not fulfill all of the objectives of native prairie rehabilitation. As prairie conservationists we should be interested in ensuring that disturbed areas are returned to stable and self-sustaining conditions similar to the surrounding non-disturbed area without further environmental degradation. It may also be important that these communities establish reasonably quickly to minimize potential losses of resources and maximize the potential benefits to society. By considering the structural and functional aspects of suitable species and the potential resulting community, long term management objectives are more likely to be achieved.

The Native Prairie Revegetation Research Project has been jointly initiated by industry, government, and academia to improve our understanding of native prairie recovery following disturbance and rehabilitation.

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Table 3. Seed mixes and seeding rates for seeded treatments in the dry mixed grass portion of the native prairie revegetation research project.

Species	Seed Mix (% Pure Live Seed)		
	Current	Simple	Diverse
Western wheatgrass (*Agropyron smithii* Rydb.)	50	10	7
Northern wheatgrass (*Agropyron dasystachyum* Hook.)	30	10	7
Slender wheatgrass (*Agropyron trachycaulum* Link.)	15		7
Green needle grass (*Stipa viridula* Trin.)	5		7
Blue grama grass (*Bouteloua gracilis* Lag.)		30	22
Needle-and-thread grass (*Stipa comata* Trin. & Rupr.)		30	22
June grass (*Koeleria macrantha* Ledeb.)		20	7
Indian rice grass (*Oryzopsis hymenoides* Roem. & Schult)			3
Canada wild rye (*Elymus canadensis* L.)			7
13 forb species[H]			11
<u>Seeding Rates</u>			
seeds/m^2	300	300	300
kg/ha	10.7	6.8	9.4

[H]Forbs include: American vetch, prairie coneflower, yarrow, broomweed, purple prairie clover, tufted white prairie aster, Missouri goldenrod, ascending purple milk vetch, blanket flower, white prairie clover, old man's whiskers, sweet vetch (Hedysarum), golden bean.

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FESCUE GRASSLAND RESTORATION: INTEGRATING RESEARCH AND EXPERIENCE INTO A FESCUE GRASSLAND CONSERVATION STRATEGY

Geoffrey T. Clark

Ducks Unlimited Canada, 315 Aquaduct Drive, Brooks, Alberta T1R 1B7

Abstract: Grassland restoration is an attractive prairie conservation tool. However, applied knowledge and new techniques from research are limited, particularly on large-scale applications. Here results of a restoration experiment in the fescue prairie of central Saskatchewan are combined with restoration experiences of Ducks Unlimited and other research information. In an experiment comparing establishment of four seed mixes on knoll and foot-slope landscape positions in the black and dark-brown soil zone we found that seed mixes with more grass species established at higher rates than a less diverse mix. All seed mixes established better on knolls than on foot-slopes. All mixes established better in the dark-brown soil zone compared to the black soil zone; this is supported by Ducks Unlimited experiences restoring grassland. The higher establishment on knolls and dark-brown soils may be related to the lower weed density on these sites. We will continue monitoring this experiment to determine longer-term effects on community development and benefit for waterfowl. To optimise restoration in central Saskatchewan our results suggest using seed mixes with high grass diversity in dark-brown soils, or on dry, infertile soils in black soils. In the short-term a fescue grassland conservation strategy focussing on conserving remaining prairie rather than restoring prairie would have greater benefit, particularly in the black soils of the fescue prairie where restoration has been less successful compared to the dark-brown soil zone.

INTRODUCTION

Since the inception of the North American Waterfowl Management Plan in 1985, Ducks Unlimited Canada (DUC) has restored thousands of acres of cultivated land throughout prairie Canada to native grasslands to create nesting cover for upland nesting waterfowl. In addition, DUC supports and conducts research in establishment and management of restored native grassland. From our experience and research we have found that the quality of restored grassland generally varies among regions. The quality of restoration is defined here as the similarity of composition, structure, and function between planted native grassland and remnant native grassland. The concept of quality would be difficult to measure in the field and I use it subjectively based on observation of hundreds of restored and remnant grasslands and discussions with Ducks Unlimited field staff across Canada. For the reason of possible subjectivity I discuss quality differences at a gross scale where differences appear most obvious.

The quality of restoration in a grassland type should be a factor in determining a grassland conservation strategy for the region. For example, if restoration is successful and quality appears high, then it may be considered as part of a grassland conservation strategy, depending on other considerations such as amount of remnant prairie remaining, risk of future deterioration and loss of remaining prairie, and quantity of restoration possible. How restoration quality in relation to these other considerations may affect a grassland conservation strategy will be discussed using fescue prairie of Saskatchewan parkland as an example.

EXPERIMENTAL EVIDENCE THAT RESTORATION QUALITY IS AFFECTED AMONG REGIONS

We compared the effects of soil zone and landscape position on the establishment of four native seed mixes in the fescue prairie region near Saskatoon, SK. Two locations were used for this study. One was located in the black chernozemic soil zone near Cudworth, SK, and the other in the dark-brown chernozemic soil zone in the Allan Hills, 20 miles west of Hanley, SK. Both locations had loamy soils and were in rolling topography. At each location we selected a knoll and a foot-slope landscape position to seed the four seed mixes. Each of the four seed mixes was replicated four times and randomized at each combination of soil zone and landscape position.

Table 1. Composition and Seeding Rate of Four Native Seed Mixes. Pls lb/ac = pounds of pure live seeds/acre, pls/foot² = pure live seeds per square foot.

Species	**Mix 1**		**Mix 2**		**Mix 3**		**Mix 4**	
	pls lb/ac	**pls/foot²**	**pls lb/ac**	**pls/foot²**	**pls lb/ac**	**pls/foot²**	**pls lb/ac**	**pls/foot²**
Slender Wheatgrass	0.5	2	0.3	1	0.3	1	0.3	1
Awned Wheatgrass	0.7	2	0.4	1	0.4	1	0.7	2
Western Wheatgrass	4	10	0.4	1	0.4	1	0.8	2
Northern Wheatgrass	2	7	1.4	5	0.3	1	0.6	2
Green Needlegrass	3.1	13	1.4	6	0.2	1	0.7	3
Plains Rough Fescue			1.7	14	0.1	1	1.7	8
Western Porcupine Grass			1.5	2	3	4	1.5	2
Needle and Thread			0.4	1	2.3	6	1.1	3
Junegrass			0.02	1	0.1	6	0.09	4
Blue Grama			0.06	1	0.4	6	0.2	3
Little Bluestem			0.2	1	1	6	0.7	4
Total	**10.3**	**34**	**7.78**	**34**	**8.5**	**34**	**8.39**	**34**

Mix 1 consisted of 5 grass species and mixes 2, 3 and 4 had 11 species (Table 1). Seed mix 1 represents a composition that is relatively inexpensive and available from commercial seed suppliers. The seed composition of mixes 2-4 were differentiated based on the approximate composition of climax fescue grassland in different landscape positions and soils in the region (Coupland and Brayshaw 1953, Coupland 1950). Mix 2 contained a high proportion of species expected to persist in mesic fertile soils and mix 3 contained a high proportion of species expected to persist on dry soils. The composition of mix 4 was medial between mix 2 and 3.

The four seed mixes were seeded at a rate of 34 pure live seeds/ft² in mid-June of 1996. Establishment (measured as seedling density) data were collected in August 1996 and August 1997. Above-ground green biomass of planted species was clipped at ground level in August 1997 and was dried and weighed. Data were analyzed using analysis of variance. Only the 1997 data are presented here.

Results

All seed mixes established better in the dark-brown soil zone (Table 2) and on knolls (Table 3). Biomass production was greater in the dark-brown compared to the black soil zone and was greater in foot-slope landscape positions compared to knolls (data not shown). Mix 2 established at the highest rate, while mix 1 established at the lowest rate in both soil zones and landscape positions (Table 4). Biomass production was similar among seed mixes averaging 60g/m². Soil nutrient analysis indicated lowest levels of fertility occurred on knolls and in the dark-brown soil zone (Table 5).

Table 2. Soil Zone Effect on Total Establishment. Means with different letters are significantly different.

Soil Zone	Plants/ft²
Black	3.11[a]
Dark-Brown	4.05[b]
%5 LSD=0.50, SE=0.24	

Table 3. Landscape Position Effect on Total Establishment. Means with different letters are significantly different.

Landscape Position	Plants/ft²
Knoll	4.03[a]
Footslope	3.13[b]
%5 LSD=0.50, SE=0.24	

Table 4. Seed Mix Effect on Total Establishment. Means with different letters are significantly different.

Seed Mix	Plants/ft^2
Mix 1	2.87^{a}
Mix 2	4.31^{c}
Mix 3	3.36^{ab}
Mix 4	3.78^{bc}
%5 LSD=0.7, SE=0.34	

Although the black soil zone and foot-slope landscape position had the highest fertility, establishment was greatest on knolls and in the dark-brown soil zone. Adding nitrogen to tallgrass prairie soils reduces the competitive ability of native grasses against weedy grasses and causes a shift towards a weedy community (Wedin and Tilman 1990). Most native grasses establish slowly and resist weed invasion poorly during the establishment phase of a planting (Duebbert et al. 1981). In this study, observed densities and biomass of the perennial exotic species quackgrass (*Agropyron repens*) and Canada thistle (*Circium arvense*) were much greater in sites with high soil nitrogen. Differential establishment between soil zones and landscape positions may be related to high weed densities caused by differential fertility between soil sites. These results indicate that differences between regions (black and dark-brown soil zone) and soil types (infertile knolls and fertile, mesic footslopes) may effect establishment of native grassland.

The seed mixes with more species and relatively high amounts of fescue had higher seedling densities than the other mixes. Mix 3 had a seedling density similar to the less species-rich mix likely because needle and thread (*Stipa comata*) and western porcupine grass (*Stipa curtiseta*) were seeded at high rates in this mix and establishment of these species was poor in all mixes (data not shown). Adding new native species as seed to mature but species-poor tallgrass prairie increased diversity and productivity and did not reduce production from the original species in the community (Tilman 1997). This indicated that the new species were not competing with existing species for resources in the community, but rather filling open niches. Better niche separation among two of the three seed mixes with greater species richness may account for the better establishment compared to mix 1.

Table 5. Available Nitrogen (N), Phosphorus (P), and Potassium (K) (micrograms/g) on knoll and footslope landscape positions in black and dark-brown soil zones.

	Soil Nutrient		
Black Soil Zone	N	P	K
knoll	3.1	16	190
footslope	7.6	9.2	330
Dark-Brown Soil Zone			
knoll	1.4	3.1	128
foot-slope	2.6	9.1	272

OBSERVATIONAL EVIDENCE THAT RESTORATION QUALITY IS AFFECTED AMONG REGIONS

Three regions across the Canadian prairies have resulted in three general experiences of restoration for our company. The regions are the brown and dark-brown soil zone and the black and degraded black soil zone of Saskatchewan and Alberta, and the black soil zone of Manitoba. These soil zones roughly approximate the mixed prairie, the fescue prairie and western parkland, and tallgrass prairie and eastern parkland, respectively.

Black soil zone of Manitoba (tallgrass prairie and eastern parkland)

DUC has been involved in restoring grassland in southwest Manitoba for more than ten years. Our first seed mixes contained only native cool season grasses, but we quickly moved to add warm season grasses that are common in the region such as big bluestem (*Andropogon gerardii*), indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), little bluestem (*Schizachyrium scoparium*) and sideoats grama (*Bouteloua curtipendula*), and have experimented with adding forbs and shrubs. The relatively high number of native species available for planting has aided our restoration program in this region.

Use of proven techniques (Wark et al. 1995) has resulted in good establishment and performance of the stands. Several years after establishment these plantings have a mix of tall and mid grasses and a structure similar to remnant grassland. These stands also function similarly to remnant tallgrass prairie as the composition and production of planted species varies similarly from effects of fire, rest, and drought. The species richness of these plantings compared to remnant grassland, however, is relatively low. Considering the small amounts of fragmented tallgrass prairie remaining, it is unlikely that native species richness will increase quickly in our plantings, to a level similar to remnant grassland.

Brown and dark-brown soil zone of Saskatchewan and Alberta (Mixed prairie)

In this region we have restored grassland for 5-6 years. The most common seed mix used contains western wheatgrass (*Agropyron smithii*), northern wheatgrass (*A. dasystachyum*), slender wheatgrass (*A. trachycaulum*), and green needle grass (*Stipa viridula*). This mix lacks many of the dominant species found in mixed prairie such as blue grama (*Bouteloua gracilis*), june grass (*Koeleria gracilis*), needle and thread grass and western porcupine grass and we are adding these species as seed supplies become available. A definite advantage to restoring prairie in the brown and dark-brown soil zone is that perennial weeds such as quackgrass and Canada thistle are less competitive with native grass plantings on most sites. These perennial weeds are a particular problem in the black soil zone and can infest a planting and compromise establishment and performance of restored prairie.

Compared to pristine mixed prairie the structure and function of our restored mixed prairie suffers somewhat because we lack seed for dominant species common to this ecosystem. We have found, however, in many cases that native species re-establish in our plantings from the seed bank and adjacent prairie which increases total species richness. Over several decades our plantings that are beside large areas of mixed prairie likely have the greatest potential to most resemble a pre-cultivation mixed grassland community because of movement of plants from the undisturbed prairie into the planted community.

Black and degraded black soil zone of Saskatchewan and Alberta (Fescue prairie and parkland)

DUC has planted native grass mixes in the black and degraded black soil zone of Saskatchewan and Alberta for about 6 years. Seed mixes contain western wheatgrass, slender wheatgrass, northern wheatgrass, green needle grass and awned wheatgrass (*Agropyron subsecundum*). Other species that would be appropriate for this region have been used less frequently due to a lack of availability. Plains rough fescue (*Festuca hallii*) is a species that characterizes native prairie in the region, yet availability of this species is poor.

In general, the quality of native plantings in this region has been poor compared to the mixed and tallgrass prairie regions. Invasion of perennial weeds is a serious problem throughout the region. In addition, production from the seeded grasses is often less than anticipated. These problems generally become more severe as one moves west in the parklands from eastern Saskatchewan into Alberta.

Possible reasons for poor performance are complex and may involve many factors. Some possible reasons include: poor composition and diversity of seed mixes; seed used was moved beyond ecological tolerance; establishment, weed control, and management techniques developed primarily in other regions do not work; perennial exotic weeds are difficult to control in this region; ecological conditions of cultivated soils in the region are relatively poor for establishment of native plants. In some situations we have been able to establish productive native stands using this mix, however, results have been unpredictable. Our restoration efforts have been scaled back in this region until solutions are developed to establish native grassland that will maintain or improve in quality.

MANAGEMENT IMPLICATIONS FOR CONSERVING PRAIRIE – FESCUE PRAIRIE IN SASKATCHEWAN'S PARKLAND AS AN EXAMPLE

The fescue grassland of the Saskatchewan parkland is an example of one of several grassland ecosystems that is relatively rare. Looman (1969) estimated that 90% of the plains rough fescue prairies had been altered by agricultural activities by the late 1960's. Less than 5% of this grassland remains in Saskatchewan's parkland today (Burns et al. 1991). In the last ten years there has been considerable interest in maintaining what is left of this ecosystem.

In order to conserve grassland ecosystems, two general conservation strategies are possible. The first is securing remnant native tracts through purchases, conservation easements, or other means, and the second is restoring grassland on degraded or cultivated sites. Four factors should be considered before determining a strategic conservation direction: 1) amount of prairie remaining; 2) risk of future deterioration and loss of remaining prairie; 3) quantity of restoration possible; and 4) quality of restoration.

Information that can be used to determine the relative mix of restoration and securement for fescue prairie in Saskatchewan is scarce. Only a few generalities are available. Firstly, we know that relatively little fescue grassland remains in Saskatchewan's parkland. The threat to this remaining grassland is largely unknown, but considering the small amount remaining, any future losses will represent a large loss to regional biodiversity. The second consideration is that large scale restoration of fescue grassland in Saskatchewan has yet to be consistently successful, and experimental evidence suggests that establishment of native species is reduced in black chernozemic soil in the fescue prairie region compared to less fertile soils. Thirdly, restored grassland often lacks qualities of remnant grassland such as species richness desired by conservationists. Another consideration is that securing remnant grassland is often less expensive than restoring grassland; cultivated land is generally more expensive than rangeland and restoration costs (seed, equipment, management) can be very high.

Considering that restoration success of fescue prairie is spurious, the amount of fescue prairie remaining is small, and any further losses are relatively high because of the small amount remaining, fescue grassland conservation efforts should focus on securing remaining fescue prairie remnants. Restoration of fescue grassland should remain a secondary tool for conserving fescue grassland. Restoration should be considered in conditions where success may be higher such as on less fertile soils and with diverse mixes that contain appropriate species.

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CONSERVATION CASE STUDIES

CANADIAN FORCES BASE SUFFIELD NATIONAL WILDLIFE AREA

Garry Trottier

Canadian Wildlife Service, 200-4999 98th Avenue, Edmonton, Alberta T6B 2X3

Abstract: A 458 square kilometre tract of mixed prairie grassland at Canadian Forces Base Suffield, Alberta, which has been protected from military training exercises since 1970, has been reserved for designation as a National Wildlife Area under the Canadian Wildlife Act. Consequently, a comprehensive ecological inventory was undertaken to aid preparation of a management plan. The inventory results confirm this area as an unbelievable important prairie grassland refugium worthy of protected area status. Formal designation and management considerations present unusual challenges which will be discussed.

THE NEW ALBERTA PRAIRIE CONSERVATION ACTION PLAN

Ian W. Dyson

Alberta Environmental Protection, Bog 3014 YPM Place, 530 8th Street South, Lethbridge, Alberta T1J 2J8

Abstract: An Alberta Prairie Conservation Action Plan (PCAP), 1996-2000 has been produced by the multi-party Prairie Conservation Forum (PCF) and published with a Foreword by the Minister of Alberta Environmental Protection (February 1997). The Alberta PCAP has four goals addressing: information and research; legislation and policy; landscape/ecosystem management; and education and awareness. Examples of current implementation activity related to each goal are highlighted. A summary of PCF initiatives addressing research, communications and municipal involvement is provided and development of a university course in Prairie Conservation is detailed. The article concludes with an evaluation of the challenges and opportunities facing successful implementation of PCAPs in Alberta.

INTRODUCTION

The Alberta Prairie Conservation Action Plan (PCAP), 1996-2000 was produced by the Prairie Conservation Forum (PCF[1]) and published with a Foreword from the Minister of Alberta Environmental Protection in February 1997. The role of the PCF and the process used to develop the Alberta PCAP are detailed in previous Proceedings of this series of workshops (Dyson 1996). This paper highlights the content and selected accomplishments of the new PCAP, outlines current PCF initiatives, provides detail on one initiative, a Prairie Conservation Course at the University of Lethbridge, highlights selected prairie conservation activities being undertaken by cooperating PCF partners, and concludes with a brief assessment of current Alberta prairie conservation weaknesses and strengths.

CONTENT OF THE ALBERTA PCAP

Care was taken in crafting the new Alberta PCAP to ensure continuity and consistency with the direction and thrust of its parent, the original prairie-wide PCAP, 1989-1994 (World Wildlife Fund Canada 1988). It is, however, structured differently. Whereas the original PCAP had ten goals with subsumed action recommendations, the Alberta PCAP has adopted a three-tiered structure with goals, objectives and action recommendations. The goals state a desirable future condition for broad themes (e.g., ecosystem management) while the objectives focus on key theme components (e.g., reclamation/restoration) and the actions focus on direct courses of action (e.g., identify sites/adopt management strategies) that are defined temporally and spatially where appropriate.

The four Alberta PCAP goals address information and research, the legislative and policy environment, landscape/ecosystem management, and education and awareness. Vision, goals and objectives are identified in Table 1.

Selected highlights from current activity related to each of the goals are as follows:

Goal 1: Information and Research

- Environmentally Significant Areas inventories have been completed for all of prairie and parkland Alberta.

- A reconnaissance level inventory of native prairie vegetation for the entire GrasslandNatural Region will be completed by April 1998.

- An Alberta Ecological Information Services data base has been developed and is housed with the Canada Land Stewardship Centre in Edmonton. The data base incorporates over 30,000 bibliographic references relating to prairie systems, a

[1]A thirty plus member multi-party committee comprising representatives of agricultural and environmental interest groups, NGO's, regulatory Boards, academia, industry and all three levels of government. It has been in existence as a networking and information exchange forum for prairie and parkland conservation initiatives since 1989.

Table 1 Alberta PCAP: vision, goals and objectives.

ALBERTA VISION 1996-2000

The biological diversity of native prairie ecosystems in Alberta is conserved for the benefit of current and future generations.

GOAL 1

Advance the identification, understanding and use of information about Alberta's prairie ecosystems.

OBJECTIVES

1.1 Complete identification of remaining native prairie by 1998.
1.2 Improve the accessibility and use of available information.
1.3 Promote research and encourage the integration of research and inventory efforts.
1.4 Ensure that research and inventory results are applied to ecosystem management in the prairies.

GOAL 2

Ensure governments at all levels have in place policies, programs and regulations that favour the conservation of Alberta's native prairie ecosystems.

OBJECTIVES

2.1 Ensure management policies applied to Crown land under grazing disposition are compatible with the retention of existing native prairie landscapes.
2.2 Amend or remove policies and legislation detrimental to the conservation of Alberta's native prairie.
2.3 Ensure all new policies and the legislation, regulations and activities arising from them are in accordance with the Alberta PCAP.
2.4 Encourage the development and implementation of new policies and programs at all levels that promote the conservationof prairie ecosystems.

GOAL 3

Adopt land use management practices and protective strategies across the whole prairie landscape that sustain diverse ecosystems.

OBJECTIVES

3.1 Encourage the adoption of ecosystem management practices to sustain and conserve all prairie landscapes.
3.2 Determine the biotic and abiotic requirements of native prairie species and communities and incorporate these in management practices to sustain these requirements.
3.3 Provide specific protection for significant, representative and sensitive ecosystems.
3.4 Actively pursue the reclamation of degraded ecosystems.

GOAL 4

Increase awareness of the values and importance of Alberta's native prairie ecosystem.

OBJECTIVES

4.1 Promote an understanding and appreciation of our native prairie ecosystems amongst the public.
4.2 Promote an understanding and appreciation of our native prairie ecosystems amongst users of prairie land scapes. Provide information and resources to assist landowners and lessees in conserving prairie habitats on their land.
4.3 Encourage the incorporation of prairie ecosystems and prairie conservation into the education curriculum at all levels.

habitat requirement data base for key species and a data base of expert contacts.

- An Alberta Natural Heritage Information Centre (Conservation Data Centre) has been established by Alberta Environmental protection in partnership with the U.S. Nature Conservancy and Parks Canada.

- A Biodiversity/Species Observation Database is being established to store pertinent information (date, location, species, observer, etc.) on species observations for species of concern (red and blue listed) and species whose status is undetermined. A full time project manager has been hired by Environmental Protection's Wildlife Management Division.

Goal 2: Legislation and Policy

- A committee of government MLAs, the Agricultural Lease Review Committee has been consulting with Albertans on public lands issues in the White Area (settled area) of the province, with particular emphasis on agricultural leases. Almost 2,000 people attended 23 public meetings in twenty locations in late October and November 1997 and the committee heard from 259 presenters. Written briefs were accepted until 31 December 1997. The committee's initial observation and recommendations will be available for public review and comment later in 1998. The majority of Alberta's key native prairie rangelands landscapes are White Area Crown lands under lease. Maintaining these Crown native rangelands under long term leases received strong support at the public meetings.

Goal 3: Landscape/Ecosystem Management

- A framework for prairie ecosystem management has been developed (Bradley and Wallis 1996).

- The 'Cows and Fish' program has enlisted the cooperation of 11 southern Alberta ranches that have applied riparian grazing strategies to restore riparian condition. Two rural municipalities are now cooperating with the Cows and Fish partners in a watershed scale application.

- The provincial Special Places program is identifying protected sites to represent the natural landscapes of Alberta. Eleven candidate sites have been identified in the Grassland Natural Region. Local committees chaired by the affected host municipality are charged with assigning and making recommendations on each site.

- Native Plant Revegetation Guidelines are being developed for Alberta's natural landscapes and a six year multi-partner Native Prairie Revegetation Study is underway to assess the efficacy of various prescriptions in restoring oil and gas well sites. Efforts are also underway to increase availability of commercial supplies of key native species through the Native Plant Development Project.

Goal 4: Education and Awareness

- Recent extension products associated with the 'Cows and Fish' program (see Goal 3, above) include a video 'Along the Waters Edge' and an educational game show for kids 'Cows, Fish, Cattle-dogs and kids' which has been successfully marketed through theme weeks such as Environment Week, provincial parks interpretive programs and 'Aggie Days'.

- Various educational materials and programs for schools are being implemented including a Prairie and Grasslands Poster Kit, an interactive program about threatened species based on 'Hollywood Squares', and threatened species presentations on the Peregrine Falcon and Northern Leopard Frog.

PRAIRIE CONSERVATION FORUM INITIATIVES

The Prairie Conservation Forum has developed an Implementation Strategy for the Alberta PCAP (Prairie Conservation Forum 1997a) identifying for every action recommendation the interested and affected organizations, actions required, resourcing needed and relative priority. Many of these actions are underway with resources committed and lead organizations in place. The Forum does not closely 'police' implementation actions. Rather, members provide updates at each Forum meeting, member input is solicited to report implementation highlights in the Forum's bi-annual reports, and a detailed assessment of accomplishments is envisioned for the conclusion of the five year implementation period, as was done for the original PCAP (Prairie Conservation Forum 1997b). The Forum is, however, focusing its collective resources selectively on areas of the Alberta PCAP where a clear implementation onus does not exist or where effective collaboration between numerous parties is required to achieve progress. These areas include research, communications, municipal involvement and development of a university course. The last item is detailed in the next section, the others are summarized as follows:

- Research
  The Forum has established a Prairie Ecology Research Committee under the leadership of the Canadian Wildlife Service involving universities, research councils, agencies and organizations having a direct interest in ecological research and inventory activities in prairie and parkland Alberta. The intent is to avoid overlap, improve communications and to identify priority research areas to maximize applied management benefit. As an initial step, a contract was let to analyze recent prairie natural resource information and research gaps and to determine future directions and need.

- Communications
  A work group has been struck to develop a two year campaign to promote an understanding and appreciation of native prairie ecosystems amongst the public. Concept proposals are being developed for an awareness pamphlet and a travelling exhibit and background papers have been drafted to provide information on four key messages: description of the prairie landscape; changes to the prairie landscape; values associated with native prairie; and tools for managing native prairie landscapes. These materials will be finalized in 1998. A PCF Homepage has also been established (http://www.rr.ualberta.ca/profs/lmorgant/ praicons.htm).

- Municipal Involvement
  With the demise of the six regional planning commissions in prairie and parkland Alberta, municipal involvement on the Prairie Conservation Forum has been weakened. This has occurred simultaneously with municipalities having to assume significant new duties, including responsibility for the implementation of Provincial Land Use Policies. Many rural municipalities have very limited resources and little time for environmental issues. Yet they face significant current issues including rural subdivision and land fragmentation, the disposition of tax recovery lands, a rapidly expanding intensive livestock industry, the Special Places Program and reclamation and weed issues. Forum members are evaluating ways to enhance municipal involvement in Forum activities and the use of Forum expertise and resources to assist municipalities in ways that are practical and of applied value.

TOPICS IN PRAIRIE CONSERVATION

A Forum work group met throughout 1997 to develop a senior seminar course to be offered at the University of Lethbridge in the fall of 1998. The course will address the whole prairie landscape, with emphasis on native prairie conservation.

The course will provide students with an overview of the prairie landscape including: the climatic, biotic and physical forces that have shaped the prairie landscape; native and Euro-centric perceptions of the landscape and its utilization; patterns of land use during and following European settlement; macro-economic trends affecting land use; the roles and responsibilities of all three levels of government; and the current state of knowledge about the prairie environment including research directions, information sources and information gaps. Particular emphasis will be placed on current natural resource management issues, including ecosystem management in urban and industrial landscapes, best management practices on cultivated landscapes, range management on native grasslands, protected areas and endangered species management, and the revegetation of disturbed areas. The penultimate module will address influencing public policy decisions using an example of a regulatory hearing process and also will address public education and awareness. The course will conclude with a student survey to determine changes in students' knowledge and attitudes since the beginning of the seminar. Key course modules are listed in Table 2.

The structure of the course is modelled on that of the Alberta PCAP, and Alberta's ecosystem management framework (Bradley and Wallis 1996) will be used to expose students to the dynamic nature of ecosystem processes, linkages between these processes, ranges of natural variation and indicators of sustainability.

Forum members and other volunteer professionals will deliver the course. Detailed outlines have been developed for each module of the course. In addition to classroom instruction, students will be involved in presentation, lab work, role plays and field trips. Once the course has been delivered a comprehensive file of instructional materials and resources will be compiled and this will be available to other institutions who would like to deliver this course or modify it (e.g., week long graduate block courses) for their own purposes.

Table 2. Topics in prairie conservation course outline.

1	Alberta PCAP; Prairie ecosystem management
2	The Prairie Landscape: physical environment; biotic environment; ecological processes and classification
3	The Cultural Environment
4	Economic and Institutional Context for Prairie Conservation
5	Information and Research
6	Prairie Ecosystem Management in Urban and Industrial Landscapes
7	Cultivated Landscapes
8	Native Rangelands
9	Protection and Conservation of Native Prairie Ecosystems
10	Revegetation of Disturbed Prairie Landscapes
11	Influencing Public Policy/Decisions; Educating the Public
12	Seminar Wrap-up; Public Awareness Survey Results

RECENT ACTIVITY HIGHLIGHTS

Progressive prairie conservation efforts are underway in Alberta on a number of fronts. Cooperating partners on the Prairie Conservation Forum are delivering a variety of initiatives. Following are some representative examples.

The Eastern Irrigation District (EID) has completed range inventories and wildlife habitat evaluations on two grazing blocks totalling 11,000 ha to enhance and conserve sensitive landscapes. Population surveys for upland birds, Sharptail Grouse leks and Pronghorn Antelope are conducted annually. The district is also, in association with the province and Lethbridge Community College, assessing the feasibility of biological weed control, using grass carp, in irrigation canals and farm dugouts to replace chemical treatment measures.

Ducks Unlimited/NAWMP works closely with grazing associations and irrigation districts to conserve large tracts of native prairie. In southern Alberta 73,490 ha of native and tame grassland are under long term agreements. Ducks Unlimited research has led to an active flushing bar delivery program in the parkland to save nesting ducks in hayfields. During 1996 and 1997, 80 flushing bars were installed on mowers used to cut hay on over 7,000 ha.

The Alberta Native Plant Council conducted a field tour of the Rumsey parkland in the spring of 1997 and will be publishing a book on rare plants of Alberta in 1998.

Operation Grassland Community has negotiated voluntary habitat protection agreements, contributed to prairie rattlesnake research, undertaken a burrowing owl census, published the Operation Burrowing Owl Newsletter (the program has 224 members and 14 voluntary agreements in place), undertaken shrub planting on the Loggerhead Shrike Tail and given various presentations to public and community interest groups.

CFB Suffield has undertaken a detailed ecological inventory and management plan for the future National Wildlife Area and reintroduced elk onto the base following the removal of feral horses from the base in 1996. Using Elk Island National Park as a source, 132 elk were introduced to the base in February 1997, 29 years after extirpation occurred. Twenty two calves were born and only seven animals left the base in 1997. Another 91 elk have now been introduced in February 1998 to ensure genetic diversity in the population.

The Medicine Hat-based Grasslands Naturalists have produced a travelling exhibit on the ecology and natural values of the South Saskatchewan river valley, produced various natural history publications, and undertaken research into fescue prairie grasslands.

CONCLUSION

Continuing the successful implementation of PCAPs in Alberta faces some real challenges. Firstly, the original PCAP was released in 1988, and since 1989 Alberta has had a multi-stakeholder coordinating group in place to oversee plan implementation. That is a lifetime in a province undergoing significant structural change and in a field where the emergence and disappearance of paradigms occurs with almost meteorological rapidity. Continuing fragmentation of jurisdictions necessitates evermore complex partnerships. Resources are often seriously limited, are becoming more so, and competing priorities demand attention. Slow, incremental conservation gains in rural Alberta quickly evaporate in the face of policy initiatives on gun control, endangered spaces and endangered species. Old urban/rural stereotypes are quick to reassert themselves.

On the positive side, away from external threats, both real and perceived, there is usually unanimity and support amongst all parties when it actually comes to fixing a real problem on the ground. At its best, working in forums and partnerships is mutually reinforcing and energizing. There is a genuine and deep interest in prairie conservation which runs surprisingly deep through a broad range of sectors in society. Ranchers, petroleum workers, researchers, resource professionals and conservationists alike gain enormous satisfaction from fixing problems and managing resources more intelligently. The resource is worth it and people of stature and credibility continue to be attracted by a cause that is noble.

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SWIFT FOX PROGRAM UPDATE

Christine Roy and Lloyd Fox
Kansas Department of Wildlife and Parks, 222 Louisa, Williamsburg, Kansas 66095

Brian Giddings
Montana Fish, Wildlife, and Parks

Abstract: In 1995, the U.S. Fish and Wildlife Service found that federal listing for the swift fox was warranted but precluded by higher listing priorities. All ten state wildlife agencies within the swift fox range and several federal agencies formed the Swift Fox Conservation Team. A primary team function is the formulation of a conservation strategy document, which provides a framework for species conservation and recovery as an alternative to federal listing. This working document's conservation goal is to: "maintain or restore swift fox populations within each state to provide the spatial, genetic and demographic structure of the United States swift fox population, throughout at least 50 percent of the suitable habitat available, to ensure long-term species viability and provide species management flexibility." The document contains objectives, strategies, and activities designed to achieve this goal.

RARE PLANT CONSERVATION

RARE PLANT CONSERVATION IN ALBERTA

Joyce Gould

Alberta Environmental Protection, 2nd Floor Oxbridge Place, 9820 B 106 Street, Edmonton, Alberta T5K 2J6

Abstract: Alberta is a province represented by six natural regions, approximately 1600 species of native vascular plants, 650 bryophytes (mosses and liverworts) and 700 lichens that have been documented to date. Five hundred thirty five (535) species of vascular plants and 268 species of mosses are currently considered to be of conservation concern. This represents approximately 30 percent of the flora.

Plants are finally getting attention and several initiatives are underway that either focus on, or include, the conservation of rare plants as an objective. Examples of these initiatives include the Alberta Natural Heritage Information Centre (ANHIC), which is part of the Conservation Data Centre network, the Plant Conservation Centre of the Devonian Botanic Garden, and Special Places 2000. Provincial legislation for endangered species has also been drafted and it does include the recognition of plants. Formation of the ANHIC has facilitated the establishment of a strong network of botanical expertise for both vascular and non-vascular plants. The data in the system are then used to help with setting and conservation priorities for land use planning and management and species protection.

This presentation summarizes the state of knowledge of rare plants, both vascular and mosses, and includes a discussion of the various initiatives. It also includes a discussion of gaps in knowledge and priorities for future work.

STATE OF KNOWLEDGE

Alberta is a physiographically diverse province. At a landscape level, there are 6 Natural Regions: boreal forest, Rocky Mountain, foothills, Canadian Shield, parkland and grassland. These Natural Regions are further subdivided into twenty subregions based on differences in vegetation, climate and physical factors. The boreal forest, the largest natural region, occupies 52.34% of the total area of the province. The grassland occupies 14.54% of the total land area, the foothills at 14.30%, the parkland at 9.42% and the mountains at 6.98%. The Canadian Shield lies in the extreme northeastern corner of the province and occupies 2.42% of the total land area of the province.

The province was covered by ice during the Wisconsin period and, therefore, our flora is young. However, there are parts of the province that were thought to be ice-free during the last glacial period. Examples of these include the Cypress Hills and a corridor along the Front Range of the Rocky Mountains. Species of plants may have survived in such areas although we do not have a clear idea of which ones they were or how important these refugial areas were for the recolonization of deglaciated areas.

There are approximately 1600 species of native vascular plants, 650 bryophytes (mosses and liverworts) and 700 lichens that have been documented to date. Of these, 13% of the native vascular plants and 23% of the mosses are ranked S1 using criteria developed by The Nature Conservancy, i.e. they occur in five or fewer localities in the province. Interestingly, 15% of the vascular flora is non-native and this figure is on the rise. An additional 17% of the vascular plants and 30% of the mosses are of conservation concern and are included on the provincial tracking lists. We do not have a clear understanding of the relatively rarity of other groups such as lichens and liverworts.

We are learning more about the flora with each passing year. The Flora of Alberta (Moss 1983) was last updated in 1983 and since that time forty-three new species of vascular plants have been discovered in the province. In fact, two new taxa were found in 1997 in Waterton Lakes National Park (Achuff 1998), an area that has had a lot of collecting effort over the past one hundred years. Several other species are new to the flora because of recent taxonomic revisions resulting from the Flora North America project. Several new mosses have been discovered in the province over the last two years, all resulting from fieldwork done by Drs. Dale Vitt and Rene Belland, primarily in the mountain National Parks.

If one examines the patterns of rarity in relation to natural regions, some interesting facts emerge. For example, Achuff (1998) has shown that the majority (65%) of our rare vascular plants occur in the Rocky Mountains. This is followed by the grassland (27%), parkland (27%)and then boreal forest (25%). Eighteen percent of the rare vascular plants occur in the foothills and only 6.5 % in the Canadian Shield. If one examines further the rare vascular flora of the different natural regions, one can see that 48% of the rare species of the mountains are unique to that natural region (Achuff 1998), i.e. not found elsewhere. This is followed by the grassland at 44%, the Canadian Shield at 23%, the boreal forest at 21% and parkland and foothills at 8% and 7% respectively (Achuff 1998). The low figures for the parkland and foothills are not unexpected because of the transitional nature of these Natural Regions. This pattern is not related to the size of the Natural Region. The boreal forest, for example, our largest subregion, has the one of the fewest numbers of rare vascular plants on a per unit area basis.

These figures are slightly different for mosses where 42% of the S1 ranked species have a boreal distribution, 27% temperate (Great Plains) and 27% mountain (Vitt and Belland 1997).

The majority (47%) of the rare vascular plants are restricted to less than 3% of the total land area of the province. An additional 33% have a range of <10% of the area, 17% have a range of <50% and only 3% are considered to be widespread in their distribution. This can be explained to a large extent by the distributional patterns of the species. The majority of our rare vascular plants are peripheral species, that is, they are at the edge of their range of distribution. An example of a species that is at the northern edge of its range is soapweed (*Yucca glauca*). A species that is at the southern edge of its range is woolly lousewort (*Pedicularis lanata*). Very few of our species are endemics, restricted to a small geographic area. Hare-footed locoweed (*Oxytropis lagopus* ssp. *conjugans*) is an example of an endemic species. It is found only on preglacial gravels in extreme southern Alberta and adjacent Montana. Few of our vascular species are disjuncts, that is, they are separated from their main centres of distribution by at least 500 km. Wood anemone (*Anemone quinquefolia*) is a good example of this. In Alberta, it is known only from the foothills of the western portion of the province. The closest known population is in Saskatchewan. Dynamic habitats such as the sanddunes on the shores of Lake Athabasca provide conditions for the rapid evolution of taxa. At least four vascular taxa are known to occur here in either Alberta or adjacent Saskatchewan, including sand-dune chickweed (*Stellaria arenicola*). A few of our rare vascular plants are widespread in their distribution and are rare wherever they are found. Bog adder's mouth (*Malaxis paludosa*) falls into this category.

Although the mountain Natural Region harbours the largest number of rare vascular species, there is a pattern of distribution of rarity within it. The region south of Crowsnest Pass is extremely diverse and has the largest number of rare vascular plant species within the mountains and within the province as a whole. Many of these plants are common in areas further to the south; they just reach the northern edge of their range in southwestern Alberta.

Other species are members of the arctic flora and just reach into Alberta from the north. This results in another cluster of rare species in the northern Rockies, in the Jasper area. There is also a difference in floristic composition between the Main and the Front Ranges and areas like Cardinal Divide are botanical hotspots. There is some evidence to suggest that this area was a refugium during the Wisconsin but this is an area of considerable dispute and discussion.

This pattern is slightly different for mosses, however. Vitt and Belland (1997) have shown that the northern Rockies have the highest rare species richness and this decreases southward.

MONITORING

Very little attention is given to monitoring rare plant populations at this time. A protocol for monitoring western blueflag (*Iris missouriensis*) populations was developed several years ago, however lack of funding has prevented any subsequent work at all but one site. Monitoring of two populations of rare vasculars, smooth boisduvalia (*Boisduvalia glabella*) and small upland evening primrose (*Camissonia andina*) is being done as part of a larger monitoring program for the Milk River Natural Area in extreme southeastern Alberta. These two species are annuals with very specific habitat requirements. The *Boisduvalia* is restricted to the edges of ephemeral drainages and the *Camissonia* to the edges of blowouts. We have been counting the numbers of plants at this site for seven years now and have noticed extreme fluctuations in population size. These fluctuations can be attributed to climate rather than any management activity on the site. We hope to continue monitoring these populations over the next few years.

INITIATIVES

Alberta Natural Heritage Information Centre

The Alberta Natural Heritage Information Centre was formally established in 1996 as a three-way partnership between The Nature Conservancy, Canadian Heritage-Alberta Region and Alberta Environmental Protection. The Centre is one of a network of Conservation Data Centres and Natural Heritage Programs throughout the United States and Canada.

We tapped into a body of experts to help with the formation of the plant tracking lists at the start of the operation of the Centre. We formed two groups, one for mosses and one for vascular plants. These groups meet annually to discuss ranks and other technical issues related to the tracking lists. The formalization of this process has had great benefit for us. The members of the group are our greatest allies and assist with promotion of the Centre. The meetings allow us to collectively discuss issues related to rank, taxonomy or threat. As a result, we can assess priorities for either field work or additional taxonomic review. The formation of the Centre has helped to set priorities for both land use planning and management and species protection by providing ready access to reliable information.

Increasing Awareness

Conservation of habitat through wise land-use and good stewardship is the most effective way to conserve species. Education, through fostering an awareness of all rare plants, is one of the first steps in achieving this goal. We are trying to increase awareness through the production of rare plant fact sheets, conduction of workshops and seminars and other means. One of the most exciting initiatives has been assisting with the production of a book on the rare vascular plants of the province. This is being done by the Alberta Native Plant Council and is due for publication this summer or fall. The Alberta Natural Heritage Information Centre, in conjunction with the Plant Conservation Research Centre of the Devonian Botanic Garden, is also planning a series of rare plant courses through the Department of Extension, University of Alberta. These courses will be aimed at the professional and will include a series of modules: rare plant surveys, plant identification, monitoring and legislation and policy.

Legislation

At a provincial level, endangered species are currently included in the amendment to the Wildlife Act. No plants are listed at this time; however, the Act does allow for the recognition of such. We will be producing two status reports in the next year which will be used to assess recommendation for inclusion under this legislation.

Alberta Native Plant Council

The Alberta Native Plant Council (ANPC), a not-for-profit group, is very active in the conservation of the native vascular flora of the province through the promotion of the knowledge of our flora and their habitats. The ANPC has been active in promoting rare plants through the production of rare plant survey techniques, collection guidelines, conduction of workshops and fieldtrips. They are producing the rare vascular plant book and the annual meeting in April will focus on rare plants.

GAPS IN KNOWLEDGE

Although we have made great strides in our understanding of rarity of plants in Alberta over the past few years, there are still many gaps in our knowledge. Some areas of the province, particularly the northwest, are poorly explored. We know less about the status of our aquatic species that we do of the terrestrial ones. We also know very little about the basic population biology of many of our species, including information on pollinators. The status of many of our occurrences is unknown; many have not been visited for many years and others lack information on population size. Another area in which we have limited knowledge is that of genetic diversity for both the rare and common taxa.

CURRENT ACTIVITIES

Highlights of some of the current activities being done by the Alberta Natural Heritage Information Centre include:

- assistance with rare vascular plant book by the Alberta Native Plant Council
- developing and implementing a series of rare plant courses through the University of Alberta Department of Extension. Modules include survey techniques, monitoring and identification workshops

- identification of botanically significant sites as part of the provincial protected areas planning process (Special Places)
- production of a framework for conservation of bryophytes (Drs. Dale Vitt and Rene Belland)
- production of a framework for conservation of genetic diversity (Dr. Brett Purdy)
- continuation of monitoring at Milk River Natural Area

PRIORITIES FOR FUTURE WORK

Priorities for future work of the Alberta Natural Heritage Information Centre include:

- development of tracking lists for macrolichens and liverworts
- field checking of historic occurrences
- preparation of status reports as a prelude to consideration for designation under provincial endangered species legislation
- determining priorities for seed collection and storage of rare vasculars (Plant Conservation Research Centre, Devonian Botanic Garden)

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PLANT CONSERVATION IN SASKATCHEWAN FROM THE PERSPECTIVE OF PROTECTIVE LEGISLATION

Sheila Lamont

Saskatchewan Conservation Data Centre, 326-3211 Albert Street, Regina, Saskatchewan. S4S 5W6

Abstract: Until recently there has been no legislated protection for the plants of Saskatchewan. Only one species, the Western Red Lily, the floral emblem of the province was recognized as needing protection from overuse or destruction. The Provincial Emblems and Honours Act exempted this species from picking, digging, etc., but even that species was not protected from destruction by tillage, road construction, building establishment or any other resource use or extraction. Even primitive societies had rituals which protected the plant species upon which they depended from being overused or destroyed. Amendments to the Wildlife Act in July of 1997 have placed plants within the scope of the resources that can be protected and managed within the provincial boundaries. The new legislation is resulting in the formation of new scientific groups to determine which of our species are within the categories rare, threatened and endangered and these will be listed in the regulations of the act and recovery plans developed for their management. The new legislation will affect the future way that resources are developed in the province and will result in new agreements such as conservation easements being used to conserve our plant heritage.

INTRODUCTION

Humankind is entering an era where concern for other life on earth is reaching new levels, as we realize that environmental degradation and the loss of species and genetic diversity is the direct result of human activities.

Human Interaction with the Environment - Changes over Time

How have we arrived at the point we are at today? H umans are believed to have arrived in North America via a route across the Bering Strait. We could refer to this as the Asian invasion - hunters and gatherers crossed into North America and began to exploit the resources that the animal and plant life there provided. Primitive hunting and gathering societies often developed rituals that protected against overutilization of the species that they depended upon for survival. The hunting and gathering mode of life does not lend itself to high populations and does not have a high impact on the natural communities present on the land. Gatherers did not tend to destroy populations of plants useful to them. Primitive agriculture was not extensive and did not permanently alter the vegetative component of the landscape.

Following the "discovery" of America by Columbus and others, the European invasion brought vast numbers of new immigrants to North America. These new people included agriculturalists. With horses and cattle to help them and ploughs to speed the progress, the new settlers began to rapidly change the face of the earth. This progress has only accelerated over the years, until finally we have realized we were taking away the habitats necessary to the survival of the species. Native vegetation has largely been replaced with imported crops and cultivars. As long as the native plants persisted within the seed bank, and the distances between their sites of occurrence remained small, the native communities continued to reestablish themselves after human influence was removed, as has been seen along old road allowances and abandoned railways. But as distances between undisturbed sites increased, and as competitive exotic species were introduced, the chances for survival of the native species and their reestablishment in disturbed areas decreased exponentially.

International accord to the idea that we must act now to reduce the loss of biodiversity was granted at the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro, Brazil in June 1992. Canada signed the accord at the Earth Summit in June 1992 and with the support of provincial and territorial governments, Canada was the first industrialized country to ratify the convention on 4 December 1992. The Canadian Biodiversity Strategy was developed by November 1994. This paper reviews the progress in general, and of the Saskatchewan provincial government in particular, towards the goal of preserving the biodiversity of plant species within its borders, in support of that biodiversity strategy developed by the United Nations.

ACCORD ON BIODIVERSITY

Objectives Of The Biodiversity Convention were stated as follows:

- the conservation of biodiversity
- the sustainable use of biological resources
- the fair and equitable sharing of the benefits that result from the use of genetic resources.

Further to that we can add the Canadian strategic goals:

- To conserve biodiversity and sustainably use biological resources
- To enhance both our understanding of ecosystems and our resource management capability
- To promote an understanding of the need to conserve biodiversity and sustainably use biological resources
- To provide incentives and legislation that support the conservation of biodiversity and the sustainable use of biological resources
- To work with other countries to conserve biodiversity, use biological resources sustainably and share equitably the benefits that arise from the utilization of genetic resources.

Saskatchewan is in the process of developing a Biodiversity Strategy and at this time, a partial draft has been prepared.

THE PROVINCIAL PICTURE

The Emblems and Honours Act

Until recently, the only legislation that provided any protection for a plant species was The Provincial Emblems and Honours Act. Our provincial floral emblem was selected in 1941 and was included in legislation in the Provincial Bird Act in 1945. The Provincial Emblems and Honours Act Part II, Section 6 now reads:

The flower known botanically as *Lilium philadelphicum* L. var. *andinum* (Nutt.) Ker and called the "western red lily" is the floral emblem of Saskatchewan. 1988, c.P-30.2, s.6.

Section 13 is in respect of offence and penalty regarding the floral emblem and states:

(1) No person shall pick, cut down, dig, pull up, injure or destroy, in whole or in part, whether in blossom or not, the plant that produces the flower that is the floral emblem of Saskatchewan.

(2) Subsection (1) does not apply to any person engaged in:

(a) the lawful carrying out of any public work or of his occupation; or
(b) the carrying out of necessary work on property owned or lawfully occupied by him.

(3) Any person who contravenes subsection (1) is guilty of an offence and liable on summary conviction to a fine of not more than $500. 1988. CP-30.2. s.13.

If anyone has ever been convicted of contravention of this act, it has not become wide public knowledge. It is difficult legislation to enforce.

The Parks Act

The only additional Act which specifically protects plants is the Parks Act. For lands under its jurisdiction it has a general prohibition:

59 No person shall:

(a) take, damage or destroy a flower, plant, shrub, tree or any other natural vegetation on park land without the prior written consent of the minister;

In Part X. Dispositions

(2) Without limiting the generality of subsection (1), no person shall:

(g) remove plant material, soil, rock or gravel from park land;

CONSIDERATION OF RARE PLANTS

In the 1970s and 1980s information on rare vascular plant species was compiled at the National Museum of Canada into a series of publications on the separate provinces. The curators and associates of the provincial herbaria and other knowledgeable people were consulted about the plants which they considered to be rare. For our province this resulted in the publication of *The rare vascular plants of Saskatchewan* in 1979 (Maher, R.V., G.W. Argus, V.L. Harms and J.H. Hudson). Following up on this work Dr. Vernon Harms at the University of Saskatchewan's W.P. Fraser Herbarium developed a dBASE IV database (RARE) on rare vascular plants in Saskatchewan (Harms et al. 1992). Although neither of these documents on our rare species had any legal implications, they were adopted as valid lists of species that needed protection within the province. Managers began to be concerned with these species; environmental impact assessments began to include special sections on rare species; developers began to conduct "rare plant surveys" and take steps they referred to as "mitigative measures" to decrease their impact upon these species.

At about the same time COSEWIC - the Committee on the Status of Endangered Wildlife in Canada began to accept and review status reports on species that were considered to be rare within Canada. In 1978 the first listings were made; in 1980 the first vascular plants were added to the list. In 1981 the first Saskatchewan vascular plant species was listed. Table 1 shows the provincial species that have been listed as rare in Canada, the year they were designated and the designation that was assigned to them. Federally listed species are accorded some protection because of their national designation as species at risk, and although there is no legislation to support it, most developers have treated these species as ones which cannot be destroyed by their constructions. Saskatchewan Regional Biologists and Environmental Protection staff required that mitigative measures to protect these plants be proposed within environmental impact assessments (EIA) and environmental protection plans (EPP). In 1994 a specialist group was added to the COSEWIC Plants Subcommittee to work with lichens, and in 1995 a similar group was added for bryophytes (mosses).

Table 1. COSEWIC Listed Species Found Within Saskatchewan.

SPECIES	YEAR DESIGNATED	COMMON NAME	RISK CATEGORY	RANK
HALIMOLOBOS VIRGATA	1992 (AB,SK)	SLENDER MOUSE-EAR-CRESS	END	S1
CYPRIPEDIUM CANDIDUM*	1981 (ON)	SMALL WHITE LADY'S-SLIPPER	END	SH
ARMERIA MARITIMA INTERIOR	1981 (SK)	[ATHABASCA] THRIFT	THR	S1S2
ABRONIA MICRANTHA	1992 (AB,SK)	SAND VERBENA	THR	S1
SALIX PLANIFOLIA TYRRELLII	1981 (SK)	TYRRELL'S WILLOW	THR	S2
TRADESCANTIA OCCIDENTALIS	1992 (AB, MB,[SK])	WESTERN SPIDERWORT	THR	S1
CHENOPODIUM SUBGLABRUM	1992 (AB, MB, SK)	SMOOTH [ARID]GOOSEFOOT	VUL	S1
YUCCA GLAUCA	1985 (AB,SK)	SOAPWEED	VUL	SE
STELLARIA ARENICOLA	1992 (AB,SK)	SAND STITCHWORT	NO DESIGNATED RISK	S3

*Report by David Macoun from Indian Head in 1895 with verified specimen; not reported since.

COSEWIC LISTED SPECIES WITH AUTHORITIES & NOMENCLATURE CHANGES

COSEWIC	**Flora of North America accepted Nomenclature**
ABRONIA MICRANTHA Torr.	*TRIPTEROCALYX MICRANTHUS* (Torr.) Hook.
ARMERIA MARITIMA (Mill.) Willd. var. *INTERIOR* (Raup) Lawrence	*A.m.* ssp. *INTERIOR* (Raup) Porsild
CHENOPODIUM SUBGLABRUM (S. Wats.) A. Nels.	
CYPRIPEDIUM CANDIDUM Muhl. ex Willd.	
HALIMOLOBOS VIRGATA (Nutt.) O.E. Schulz	
SALIX PLANIFOLIA Pursh ssp. *TYRRELLII* (Raup)Argus	
STELLARIA ARENICOLA Raup	*S. LONGIPES* Goldie ssp. *ARENICOLA* (Raup) Chinnappa & J.K Morton
TRADESCANTIA OCCIDENTALIS (Britt.) Smyth	
YUCCA GLAUCA Nutt.	

Saskatchewan Conservation Data Centre

The final column in Table 1 shows the rank assigned to the species by the Saskatchewan Conservation Data Centre (SKCDC). Established in 1992, with the sponsorship of The Nature Conservancy (U.S.A.; TNC) and the Nature Conservancy of Canada, the data centre, as one of a network of heritage programs and data centres in the United States, Canada and Central America, seeks and stores information on rare and sensitive species of animals and plants and rare and representative plant communities.

Plants, animals and communities are ranked S1 to S5 based on population, protection and threats. The SKCDC tracks occurrences of rare or sensitive taxa of S1 - S3 rank. They record data on taxonomy, geography, biology, ecology, stewardship and economic value of the species of concern.

The SKCDC list consolidated the rare species information. Some of the plants recommended as not rare in the Harms et. al summary document of the RARE database have been retained on the list. This is because the documented population does not exceed the standards of rarity accepted by TNC and adopted by the centres that form the network of information centres throughout North and Central America. These standards require that there is an unthreatened population of the species roughly equivalent to one of: more than 100 occurrences or more than 10,000 individuals or covering an area more than 50,000 acres. Individual characteristics of the species and its requirements are also factored into the equation to determine the status or rank of the species.

CURRENTLY APPLIED POLICY

As concern for rare and sensitive species has grown and there has been a resurgence of interest in native species as sources of food, medicinal products, landscaping material and craft resources, ad hoc policies have been developed to handle the new demands of native plant species as a resource. The Special Forest Products committee has worked to try to direct the growing industry and to head off problems of overutilization and abuse before they can develop. The Native Plant Society of Saskatchewan has promoted guidelines that should prevent wildcrafters and native seed harvesters from abusing the resource. The U.S.A. experience of the extirpation of ginseng from much of its original range can provide a valuable lesson for modern "gatherers."

A permitting system has been put in place and operated by provincial area offices, whereby commercial permits are required by those who either purchase special forest products from harvesters for resale or harvest directly for sale outside of the province. Recently the requirement has been attached that the permittees will provide anticipated volume of product to be harvested. Permit and ledger returns for special forest products are forwarded to Forest Ecosystems Branch of Saskatchewan Environment and Resource Management (SERM). Personal use and berry picking are not included in this system. Species listed S1-S3 by SKCDC are not permitted to be harvested. A similar system is being followed by the SERM EcoRegions south of the forest. In the grasslands, because of the high interest in the use of native grasses in reclamation and revegetation projects, controversy is developing with regard to the acceptability of the use of cultivars and ecovars; discussions are ensuing about the distances which it is recommended that genetic material can be displaced and still be accepted as "native."

The Wildlife Act 1997

In accordance with their support of the Canadian Biodiversity Strategy, the provincial government revised The Wildlife Act on 1 July 1997 to include plants as wildlife and to include species at risk:

> 50(1) Where the minister determines that a wild species is to be classified as extirpated, endangered, threatened or vulnerable, the Lieutenant Governor in Council may, by regulation, designate and list the wild species as:
>
> (a) extirpated;
> (b) endangered;
> (c) threatened; or
> (d) vulnerable.

The Wildlife Act stated that there could be an "advisory committee appointed pursuant to section 8." A Scientific Working Group was established by Fish and Wildlife Branch in 1997 to develop policy and procedures, review status reports, recommend species for inclusion in regulations to the Wildlife Act and develop recovery plans for species included in regulations. To date the Scientific Working Group has developed policy and procedures and conducted an ongoing review of COSEWIC listed species.

Status of Plant Conservation in Saskatchewan 1997

Saskatchewan Conservation Data Centre ranks have been determined with current information for vascular plants only. In 1997, with backing of Fish and Wildlife Branch, SKCDC staff surveyed sand dune environments in Saskatchewan, and gathered population data on eight species of plants on the tracking list for the province. For some of these the additional information will result in a change in the assigned provincial rank. One COSEWIC listed species may require review. Two of the species also occupy prairie habitats and the survey did not census the populations in a meaningful way.

Activity restrictions being applied in SERM's Grasslands EcoRegion for S1-S3 vascular plants require a minimum buffer of 25 metres for developments that might affect the plants. Additional considerations are applied for extremely rare species, and developments that potentially affect drainage patterns or other micro-habitat characteristics. A beginning has been made, through summer workshops, to educate Conservation Officers in Grasslands EcoRegion in the recognition of species that are potential candidates for designation.

The Scientific Working Group is reviewing status for designation of extirpated, endangered, threatened and vulnerable species.

WHERE DO WE GO FROM HERE?

The first priority is to review candidate species and identify data gaps. Field inventory for candidate species will provide data necessary to support or refute the need for listing them. This will result in status reports on candidate species and eventually the designation of plants for regulations.

It is necessary to review current activity restrictions for their effectiveness. Each species has different requirements. One of the tasks of a "recovery plan" will be to identify those requirements and to assess the restrictions necessary to protect each species. Consideration must be given to the restriction of movement of native plant seeds, to prevent contamination of gene pools of local populations. Consideration must also be extended to non-vascular species, including bryophytes, lichens, fungi, algae and microscopic flora.

A major task of the Fish and Wildlife Branch who administer the Wildlife Act will be to establish policy and procedures for applying the protection implied by inclusion of all of plants in general within the wildlife act, and then specifically of those species that become listed in the regulations of the Wildlife Act. The next step is to educate the general public on the value of protecting wild species at risk and providing them with the means for recognizing them.

SUMMARY

In conclusion, we have been given the legal tools that we need to protect plant species within our jurisdiction. Now it is necessary to determine the best means by which to apply those tools and to list those species, beginning with those of greatest concern.

ACKNOWLEDGMENTS

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THE STATUS OF RARE PLANT CONSERVATION IN MANITOBA

Karen L. Johnson

Manitoba Museum of Man and Nature, 190 Rupert Avenue, Winnipeg, Manitoba R3B 0N2

Robert Jones

Manitoba Natural Resources, Box 24 - 200 Soulteaux Crescent, Winnipeg, Manitoba R3J 3W3

Abstract: Much has happened in the last three years in Manitoba, most of it positive for plant conservation. Several new large populations of our two endangered plants, the western prairie fringed orchid and small white lady's slipper, have been discovered in southeastern Manitoba and are now being monitored. As a result, the latter species may be downgraded from 'endangered' to 'threatened', at least on the federal level. Several wet years have also helped maintain or bring back the populations of both orchids and other rare prairie species. Other officially designated prairie species seem to be at least holding their own as do most rare or vulnerable species in the province. On the negative side, a large amount of mixed grass prairie has been lost to cultivation in southwestern Manitoba as the result of increased planting of irrigated potatoes to feed two expanded processing factories.

INDIVIDUAL SPECIES PROTECTION

The Manitoba Department of Natural Resources (DNR) has been monitoring several species of plants designated by the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as "Endangered" (likely to become extinct or extirpated in an area unless present trends/pressures on the species are removed), "Threatened" (likely to become endangered unless present trends/pressures on the species are removed), or "Vulnerable" (with low population or site location numbers). The senior author and staff of the Manitoba Museum of Man and Nature, aided by volunteers from the Manitoba Naturalists Society and other organizations, have been conducting more detailed research on two of the above species and another rare plant.

DNR's monitoring of the four Manitoba species presently designated by COSEWIC and one provincial species at risk has revealed new and/or larger populations for four out of the five species. These species and their present federal and provincial status are:

1. Small white lady's-slipper (*Cypripedium candidum* Muhl.)

Federal: ENDANGERED

Provincial: ENDANGERED

Five years of regular surveys and counts in the Tall-Grass Prairie Preserve near Tolstoi, Manitoba, found large new populations of this orchid on eight quarter-sections in the Preserve. In 1997, the annual census tallied a maximum (and record) number of 34,491 clumps (Borkowsky 1997). Removal of large amounts of heavy matted dead vegetation by fire and grazing has increased the known numbers, but not the distribution, of this plant in the area. At least 12 sites of the small white lady's-slipper are now known from Manitoba, scattered as far north as St. Laurant in the Interlake, as far west as Brandon, east to Kleefield, and south to the Prairie Preserve. The smaller populations north and west of the Preserve appear to be generally holding their own, although there are problems with human disturbance and hybridization with yellow lady's-slippers (*Cypripedium calceolus* L.) at some sites.

As a result of these larger population numbers and additional sites, COSEWIC is considering downlisting this orchid to "Threatened" nationally.

2. Western prairie fringed orchid (*Platanthera praeclara* Sheviak & Bowles)

Federal: ENDANGERED

Provincial: ENDANGERED

Additional surveys of the Tall-Grass Prairie Preserve and surrounding areas found even larger numbers of this spectacular orchid, although it is still known from only three townships in the Rural Municipality of Stuartburn in southeastern Manitoba. The five year census results on 72 quarters in this area ranged from 1,818 flowering plants in 1995 to a record 21,003 in 1996. Sixty-one percent of their best range is included within the North Block of the Preserve

(Jones unpublished data). As preliminary research indicates that there are three to four non-flowering plants for each flowering one, total numbers of orchids in the area seem to be in the 75,000 to 100,000 range (Johnson unpublished data). This makes it the largest known metapopulation (over 10,000 individuals) of this species in the world.

The DNR has also been supporting research into the distribution, management and pollinators of the orchid. The senior author has been cooperating with scientists in the U.S. studying the biology and genetics of this species and its close eastern relative. Such research indicates that late frosts, such as occurred in June, 1995, destroy the plant's flowers for that year, at least on susceptible microhabitats (Dewar 1996). Wet years, such as 1995 and 1996, appear to lead to increased flowering the following year. While there is still much to learn about the biology and ecology of this species, it appears to be secure at the present time in Manitoba.

3.Western spiderwort (*Tradescantia occidentalis* (Britt.) Smyth.)

Federal: THREATENED

Provincial: THREATENED

Two large isolated populations of Western spiderwort have been located in the sandhills regions of southwestern Manitoba. In 1997, the Routledge sandhills population contained 26,550 plants while the two Lauder Sandhills sites contained 20,323. An estimated 47,000 plants are thus known from Manitoba, restricted to only a few quarter sections.

Long-term threats to these populations include: noxious weed invasion, particularly by leafy spurge; shading and competition by encroaching woody vegetation; and overgrazing by cattle. These threats are very real in the small areas occupied by the spiderwort, as most of the plants occur on private lands. However the largest population is in a voluntarily protected Ecologically Significant Area, and a small number are also located on Crown or other conservation lands (Goulet and Kenkel 1997).

4.Western silvery aster (*Aster sericeus* Vent.)

Federal: VULNERABLE

Provincial: THREATENED (pending)

This plant appears to be declining in the province and has no known populations on securely protected sites. A thorough survey of potential sites is needed (E. Punter personal communication).

5.Great plains lady's tresses (*Spiranthes magnicamporum* Sheviak)

Federal: NO DESIGNATION

Provincial: ENDANGERED (pending)

This small prairie orchid is known only from a few sites with small populations in the Tall Grass Prairie Preserve area in southeastern Manitoba and at a few sites in southern Ontario elsewhere in Canada. Its populations appear stable but occur mostly in roadside ditches, which places it at risk from human disturbance. Counts over the past four years have been: 36 flowering plants in 1994, 738 in 1995, 2,798 in 1996, and 1,780 in 1997 (R. Jones unpublished data).

COSEWIC is presently considering two additional species which occur in Manitoba for status designation. These are

Buffalo grass (*Buchloe dactyloides* [Nutt.] Engel.) (one site also in Saskatchewan) as Threatened/Endangered, and

Hairy prairie-clover (*Dalea villosa* [Nutt.] Spreng.) (several sites also in southeastern Saskatchewan) as Vulnerable.

The Provincial Endangered Species Advisory Committee is presently considering status designation for three additional species: Riddell's goldenrod (*Solidago riddellii* Frank), Culver's-root (*Veronicastrum virginicum* [L.] Farwell) and Dwarf dandelion (*Krigia biflora* [Walt.] Blake). They will move to provide provincial designations for buffalo grass and hairy prairie-clover once these have been listed by COSEWIC.

A newly discovered fern, northern adder's-tongue (*Ophioglossum pusillum* Raf.) has been deferred for status designation until a more thorough survey of its distribution has been completed (E. Punter personal communication).

A rare tree, hackberry (*Celtis occidentalis* L.), occurs on a beach ridge at the south end of Lake Manitoba and several small sites in the sandhills of southwestern Manitoba. More survey work is needed to determine the provincial range of this species, which is some 200 km north and west of its main distribution.

Other Manitoban rare plant species of note, mainly because some effort by the senior author is going into monitoring and/or otherwise keeping track of them, include: Dutchman's-breeches (*Dicentra cucullaria* [L.] Bernh.) and small purple-fringed orchid (*Platanthera psycodes* [L.] Lindley).

Dutchman's-breeches is known from only one small site in southeastern Manitoba, approximately 200 km north of its next known location. Its population has been monitored for over 10 years and is increasing.

The small purple-fringed orchid occurs in the province only in the Buffalo Point Indian Reserve in southeastern Manitoba. The known population was drastically reduced in 1991 when the road along which most of the plants grew was widened and paved. Only one small shaded colony of approximately 30 plants remains. Although we have not been able to monitor it every year, it seems to be remaining stable or increasing. This species is another one for which a thorough survey is needed in similar areas on the reserve and in the adjacent region.

HABITAT CONSERVATION/PROTECTION

Many of the species of rare plants discussed above occur in or near the Tall-grass Prairie Preserve in southeastern Manitoba. Development of the Preserve continues to be one of the success stories for conservation of plants in Manitoba. It is still being enlarged, as a cooperative venture between the Critical Wildlife Habitat Program, Wildlife Habitat Canada, Environment Canada, Manitoba Department of Natural Resources, World Wildlife Fund, Nature Conservancy of Canada, and the Manitoba Naturalists Society. The Management Committee of the Preserve is now trying a variety of techniques, from controlled burns to different grazing regimes, to improve habitat for the rare orchids and other rare prairie species which occur on it. More information on this project is available in the paper by Jones (this volume).

New National and Provincial Parks

Wapusk National Park: Manitoba's second national park was established in 1996 in the Hudson Bay Lowlands, south of Churchill, Manitoba. This region, including Churchill, contains up to 30% of the recognized rare or vulnerable plant species within the province (White and Johnson 1980). National Park protection for this area is thus a great step forward towards insuring the conservation of these arctic, subarctic and marine species.

Negotiations for the creation of a "Lowlands National Park", in the central and northern Interlake region of Manitoba, continue between the Federal and Manitoba Governments. However there is no indication of when boundary and resource use conflicts will be settled and the park proclaimed.

New Provincial Parks and Ecological Reserves

Manitoba has established several large new protected areas in the northern one-third of the province. They occur in the northern Boreal Forest, Subarctic Transition, and Arctic zones of Manitoba. Two are provincial parks and two are parks reserves. All are closed to major resource uses such as logging, mining and hydroelectric development. Additional consultations are required, notably with First Nations, before the park reserves can be formally established as full-fledged provincial parks. These areas would protect several known rare plant species and probably others, as none of these areas have been extensively surveyed.

A new Provincial Parks Act was proclaimed in August, 1996, and a new park system designated in March, 1997. For the first time, portions of Manitoba's park system are now legally closed to major resource use activities. The categories of "Wilderness Park" and "Wilderness" and "Backcountry" Land Use Categories within individual parks prohibit logging, mining and hydroelectric development in these areas. How extensive this protection will be, and how widely it will be applied within the provincial parks system, will depend on the political will of the Government of Manitoba. However the Parks Act now gives them the tools to protect large areas of the province and thus the plant communities and plant species within them.

Two new Ecological Reserves have also been proclaimed in the last three years and at least one more is close to the proclamation stage. Parts or all of ten Wildlife Management Areas have also been designated as protected areas under the province's "Protected Areas Network". Mining, logging and hydroelectric development are prohibited in all of them. They include several areas in the more densely inhabited, and thus more threatened, southern part of the province.

OTHER RELEVANT POSITIVE DEVELOPMENTS

Manitoba Conservation Data Centre

Manitoba's Conservation Data Centre (CDC), developed in July, 1994 as a partnership between the Manitoba Department of Natural Resources, Manitoba Museum of Man and Nature, the Nature Conservancy (U.S.), and the Nature Conservancy of Canada has become a valuable resource for plant conservation in the province. It was established to create an integrated data bank and comprehensive inventory of plant and animal species and representative natural communities for Manitoba. Results from the first three years of their work include the first new list of Manitoba's vascular plants in over 35 years and a first approximation list/key of Manitoba's Terrestrial Plant Communities. The CDC's ecologist and contract botanist also conduct some field survey work on rare plants and provide status reports on candidate species to the Provincial Endangered Species Advisory Committee. CDC staff are now incorporated within the DNR, providing some security for this very useful organization.

Updating/Reprinting of *"Rare Vascular Plants of Manitoba"*

The senior author is in the final throes of updating the 1980 publication on "Rare Vascular Plants of Manitoba". A small grant is assisting with the necessary research and she has a commitment from the Manitoba Museum of Man and Nature to publish the work as an "Occasional Paper" in its series. It is expected to be out in late 1998 or early 1999.

NEGATIVE DEVELOPMENTS/LOSSES

Federal

The lack of passage of the Federal Endangered Species Act and the divesting of formerly federal environmental and conservation responsibilities to the provinces creates problems for the conservation of plants and other organisms for all provinces, including Manitoba.

Provincial/Regional/Local

Continuing conversion of grassland to agricultural land remains the major problem on a provincial level. This ongoing problem is dealt with in more detail by Janet Moore's paper in this volume.

A major example of the above problem is the recent loss of mixedgrass prairie in southwestern Manitoba. Expansion of a large potato processing factory in this region requires an additional 6,000 acres (2,430 ha) of potatoes to feed its production. At least 2,000 acres (810 ha) of mixedgrass prairie were converted to potato fields during 1996-97. It is feared that the remaining 4,000 acres may also come mainly from this habitat/community type.

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REASONS FOR PRAIRIE PLANT RARITY

Diana Bizecki Robson

Nelson Dynes & Associates Inc., 242A Cardinal Crescent, Saskatoon, Saskatchewan S7L 6H8

Abstract: The rarity of prairie plants can be attributed to both human actions and biological factors. In some cases, it is a combination of human and biological factors that cause rarity. Based on my research on rare plants in the prairies, I developed several explanations for plant rarity in Canadian grassland ecosystems.

Human perceptions and actions affect plant rarity in several ways. A plant may be considered rare in Canada because it occurs at the edge of its northern range. Rare plants may be inconspicuous due to taxonomic issues, size or dormancy. It is difficult to assess the status of inconspicuous plants since our lack of sightings may be due to the plant's low visibility and not its inherent rarity. Over-harvesting medicinal plants may be causing rarity in certain species. As well, habitat loss and fragmentation destroy and isolate plant populations contributing to their rarity.

Species biology also affects a plant's rarity status. Some rare plants appear to be restricted to the early successional stage of a plant community. Other rare plants are highly stress-tolerant and appear to have lost their ability to compete in more favorable habitats. Some rare plants require associations with mycorrhizal fungi, or pollinating or seed-dispersing animals. The distribution of and changes in the populations of associated species may contribute to plant rarity.

INTRODUCTION

Over the years there have been numerous attempts to explain the rarity phenomenon. Some biologists have attempted to develop one theory to explain the rarity of all species, an endeavor that is likely in vain. The reasons for rarity depend on the ecosystem and the taxonomic group that individual species belong to. Thus, rare rainforest species are probably rare for different reasons than rare grassland species. As well, the causes of plant rarity may differ from the causes of animal rarity.

Based on my Master's thesis research on rare plants in the Canadian prairies, I have developed several explanations for plant rarity in North American grassland ecosystems.

REASONS FOR RARITY

Northern Range Limit

Rare plants in Canada may be rare because they are at the edge of their northern range. Thus, some rare Canadian plants may be relatively common in the United States. False buffalo grass (*Munroa squarrosa*) and buffalo grass (*Buchloe dactyloides*) are examples of plants that are relatively rare in Saskatchewan but more common in the United States.

Inconspicuous

Some rare plants are inconspicuous due to taxonomic problems, size or dormancy. Part of the reason these plants are considered rare may be due to the fact that field biologists have a difficult time identifying or even finding them. Since the rarity status of plants is determined using herbarium specimens and field notes, the fewer data there are about a plant, the more likely it will be considered rare. Thus, if a factor makes a rare plant less visible, its rarity status may be partly artificial.

Taxonomically inconspicuous plants are difficult to identify because of hybridization or small key characters. Hybrid plants have features in common with both parent species making it more difficult to determine rarity; is a hybrid between a rare and a common plant considered rare or common? Key characters of some species can only be seen with a microscope, making field identification difficult. The goosefoot genus (*Chenopodium*) is a good example of a taxonomically difficult group. There are five rare goosefoot species that look very similar to the common species. Not only is there a possibility of hybridization between the goosefoot species, but some of the key characters setting the species apart can only be seen with magnification, making field identification difficult. Taxonomic problems may be affecting the sedge (*Carex*) genus as well. Because of the large size of this genus, many ecologists simply refer to these plants as *"Carex* spp." in their field notes. Not identifying sedges to species or not collecting a specimen means that rare sedges may have been encountered without anyone knowing.

Rare plants that are small in size may be overlooked by field ecologists, possibly distorting their rarity status. Moss gentian (*Gentiana aquatica*) is a good example of an inconspicuous plant due to small size. This species is only about 4 to 6 cm tall. Further complicating the discovery of this species is the fact that it grows in moist habitats where it is often hidden amongst tall sedges and grasses.

Annual plants like Dakota stinking goosefoot (*Chenopodium dacoticum*) likely experience dormancy in the seed stage, making them inconspicuous in certain years. Specific climatic conditions are probably needed to trigger their germination. This may cause a boom-and bust in the population size where a species is very abundant one year and virtually absent the next. This phenomenon is apparently quite common in ephemeral wetlands where water levels fluctuate from year to year (Grime 1979). Annual species like dwarf spike-rush (*Eleocharis parvula* var. *anachaeta*), awned and least mousetail (*Myosurus aristatus* and *M. minimus*), downingia (*Downingia laeta*) and woolly-heads (*Psilocarphus elatior*) appear to have fluctuating population sizes.

Seed dormancy is not the only kind of dormancy that can occur. Perennial plants like the largely subterranean moon-ferns (*Botrychium* spp.) can stay dormant under ground for up to ten years (Lesica and Ahlenslager 1996). While in this state, the plant would be impossible to detect.

Early Successional

Some rare plants appear to be restricted to the early successional stages of a plant community. Most of these plants are annuals but some are perennial. Early successional habitats that contain high numbers of rare plants include active sand dune complexes and animal-related soil disturbances, including some human disturbances.

Sandy habitats that often contain early successional rare plants include active parabolic dunes and blowouts. When dunes become stabilized, rare early successional dune plants disappear. Currently, three of the prairie plants on the endangered species list developed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) are found in active complexes: smooth goosefoot (*Chenopodium subglabrum*), sand verbena (*Abronia micrantha*) and western spiderwort (*Tradescantia occidentalis*).

Animal-related disturbances that rare plants occasionally inhabit include heavily grazed grasslands and burrows created by small mammals. Rare plants like Kelsey's cryptanthe (*Cryptantha kelseyana*) and gaping goosefoot (*Chenopodium hians*) have been found on these types of disturbances.

Some rare early successional species have been found growing on disturbances made by humans. Dirt and gravel roadsides passing through native prairie may contain rare plants. Along road edges and trails in the South Saskatchewan River valley, false buffalo grass (*Munroa squarrosa*) has been found. In sandy areas, small lupine (*Lupinus pusillus*) and prickly milk-vetch (*Astragalus kentrophyta*) have colonized ditches. Dark-green goosefoot (*Chenopodium atrovirens*) and blue phlox (*Phlox alyssifolia*) have been found along various human-induced soil disturbances in loamy upland habitats. Therefore, some human disturbances must mimic the types of disturbances that these rare plants traditionally colonized (Sousa 1984).

Unfortunately, the near extermination of bison and black-tailed prairie dogs, fire suppression and the introduction of exotic species have likely resulted in the loss of habitat for some rare early successional species.

Stress-tolerant

Some rare plants are very stress-tolerant. Stress-tolerant species tend to grow on heavily eroded slopes in hill lands or valleys, or in saline habitats. These habitats are nutrient poor, and usually quite arid. Plants growing in nutrient-poor habitat use the resources that are available very efficiently (Grime 1979). In saline habitats, the plants have found a way to prevent the salts from affecting their functioning. Unfortunately, rare stress-tolerant plants appear to have lost their ability to compete with other plants in more favorable habitats. Rush pink (*Stephanomeria runcinata*) and western hawk's-beard (*Crepis occidentalis*) are good examples of stress-tolerant plants; they grow only on steep, eroded, usually south-facing slopes in the Frenchman and South Saskatchewan river valleys. They have not been found growing in nearby moister, nutrient-richer, less heavily eroded areas.

Habitat Loss and Isolation

Habitat loss has caused the demise of rare plant populations. The loss of habitat also causes isolation of remaining rare plant populations. The more isolated rare plants are from each other the greater the likelihood that they will have dispersal problems. Seed dispersal and pollen exchange are inhibited if inhospitable habitat separates rare plant populations. Genetic problems due to inbreeding may surface in rare plant populations that are cut off from each other.

Habitat loss and isolation appear to be factors affecting the endangerment of slender mouse-ear cress (*Halimolobos virgata*), Saskatchewan's only COSEWIC-listed endangered plant. In Saskatchewan, cultivated fields separate slender mouse-ear populations.

Rare plants in wetland habitats are particularly susceptible to dispersal problems due to the loss and isolation of prairie wetlands. Since rare hydric species require moist habitats for germination, the likelihood that seeds or spores will reach appropriate habitat is lower the more isolated the wetland.

Lack of Associated Species

Certain plants like orchids and ferns require associations with mycorrhizal fungi (Johnson et al. 1995, Lesica and Ahlenslager 1996). If associated fungi are not present, a seedling would have a poor chance of surviving in a new habitat, limiting its ability to colonize new areas.

Pollinating animals are crucial for the reproduction of certain rare plant species. Low pollinator populations negatively affect the reproduction of insect-pollinated rare plants (Menges 1991). Some rare plants also depend on animals for dispersal of their seeds. Any factor that negatively affects pollinating and seed-dispersing animals negatively affects the plants that depend on them.

Over-harvesting

Plants that are purported to have medicinal value may become rare because of over-harvesting. As the plant becomes rarer, the market value increases, fueling the incentive to find more plants and causing greater endangerment. Over-harvesting is a particular threat to plants whose medicinal value is in the root system like seneca root (*Polygala senega*) and purple coneflower (*Echinacea angustifolia*). These two plants are becoming rarer in the wild as the demand for them increases (Harms 1997).

RARITY ANALYSIS

Rare plants may be considered rare for multiple reasons rather than just one. To demonstrate this, I will examine one of Canada's rare ferns. Prairie dunewort (*Botrychium campestre*) is a perennial moon-fern that grows in wetland habitats in southern Saskatchewan. The Saskatchewan Conservation Data Center has ranked it as globally rare (G2) and provincially extremely rare (S1). This species appears to be rare for four different reasons: inconspicuousness, habitat loss, isolation and lack of associated species.

Prairie dunewort is inconspicuous for several reasons. It is a newly recognized species that is not yet well-described in regional floras. It is very small and tends to grow in wetlands amongst taller vegetation. As well it can be dormant underground for many years. All of these factors make this species difficult to find and identify, possibly affecting its current rarity status.

The loss of wetland habitats through drainage and subsequent cultivation has likely caused the demise of many populations of prairie dunewort. The loss of prairie dunewort habitat can occur even if standing water is still present in a wetland basin. Prairie dunewort typically grows several meters away from standing water. Thus, the cultivation of wetland edges has likely eliminated additional prairie dunewort populations.

The increasing isolation of wetlands may inhibit spore dispersal into new habitats and thus gene exchange between populations. Since spores and gametophytes of this species require moist habitats for germination and fertilization respectively, upland areas between wetlands are inhospitable. Duneworts are also associated with mycorrhizal fungi. If the appropriate fungi are not present, the survival of young plants may be compromised. Therefore, this species can only colonize very specific habitats. The fewer appropriate habitats there are, the smaller the prairie dunewort population will be.

CONCLUSIONS

Rarity is affected by three different factors: human perceptions, environment and biology. Artificial boundaries and human fallibility may distort rarity status, assigning it to species because of borders and poor field data. Most rare plants on the prairies appear to be affected by environmental factors like habitat. However, some rare plants may be rare due to inherent biological factors. Finally, it is important to remember that rare plants may be rare for multiple reasons.

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GRASSLANDS

CAN NATIVE PRAIRIE BE SUSTAINED UNDER LIVESTOCK GRAZING?

Llewellyn L. Manske

North Dakota State University, Dickinson Research Extension Center, 1089 State Avenue, Dickinson, North Dakota 58601

Abstract: Grass plants, grazing mammals, and grassland plant communities evolved together. During the long period of co-evolution, grass plants developed adaptive tolerance mechanisms to compensate for defoliation by herbivores. The adaptive tolerance mechanisms are better understood when separated into two general categories: mechanisms that involve numerous changes in the physiological growth processes within the grassland plant, and mechanisms that involve numerous changes in the activity levels of the symbiotic soil organisms in the rhizosphere. These adaptive tolerance mechanisms can be manipulated with defoliation management at specific phenological growth stages to produce beneficial effects to grassland ecosystems. One of the main physiological effects from defoliation is changes in the levels of growth hormones which affect development of vegetative tillers from axillary buds. One of the main effects defoliation has on the rhizosphere is changes in activity levels of the microbes and subsequent changes in the amount of nitrogen available for plant growth. Prairie management strategies that do not incorporate defoliation by herbivores cause a reduction in rhizosphere activity and vegetative tillering which reduce grassland nutrient cycling, plant density, and herbage biomass production. Native prairie can not be sustained in a healthy condition without defoliation management. An understanding the adaptive tolerance mechanisms permits land managers to use defoliation by herbivores as a manipulation tool for ecologically sound management of our grassland natural resources. Application of defoliation management by livestock can be used to sustain healthy native prairie ecosystems.

All prairies in the northern Great Plains require management by defoliation. Defoliation management must consider the biological processes of the grass plants. Grass plants have developed biological processes as adaptive tolerance mechanisms in response to grazing during the long period of coevolution with herbivores and from the evolutionary selective forces of fire and drought. Application of defoliation management by livestock can be used to sustain healthy native prairie ecosystems when the biological processes of the grass plants are considered and understood.

Plant developmental morphology is the study and understanding of how plants grow and develop. Grass growth and development are necessary for grassland managers to understand so that they can develop plans for grazing management strategies. Managers also need a working knowledge of grass growth and development in order to understand when to apply specific management practices, to know what the effects of various management practices will have on the plant communities and to be able to anticipate the secondary effects on livestock and wildlife. This paper will attempt to explain the different parts of a grass plant, how grasses grow, how grass plants reproduce and the mechanisms and processes that permit grass plants to be tolerant of grazing.

Grass plants consist of shoots and roots. The shoot is a collective term that applies to the stem and leaves which are made up of repeated structural units called phytomers (Beard 1973, Dahl 1995). A phytomer consists of a leaf, an internode, an axillary bud, and a node (Hyder 1974, Dahl and Hyder 1977). Each shoot generally has 5 or 6 phytomers but sometimes shoots may have up to eight or more. The vegetative stem consists of a few to several nodes and unelongated internodes with the apical meristem at the highest node (Langer 1972). The node is where leaves are attached to the stem. Internodes are lengths of stem between two successive nodes. An axillary bud is a concentration of meristematic tissue capable of developing into a tiller. A leaf is divided into blade and sheath with a collar separating the two parts. The crown of a grass plant is the lower portion of a shoot and has two or more nodes (Dahl 1995).

Plant growth is a quantitative change in plant size (Dahl 1995). Growth occurs by an increase in the number of cells by cell division in meristematic tissue (growing points) and from cell enlargement and elongation. Most new cells are produced in the apical meristem which is located at the top of the crown. In some species the apical meristem remains near ground level (short shoots), and in other species the apical meristem is elevated before transforming to the sexual reproductive stage (long shoots) (Dahl 1995).

Groups of new cells in the apical meristem form growth centers and develop into leaf primordia which develop into phytomers. Almost all of the cells are formed while the leaf is a minute bud (Langer 1972). The oldest cells of a leaf are at the tip and the youngest cells at the base (Langer 1972, Dahl 1995). Elongation of cells and differentiation of cell masses into various tissue types begin at the tip of the leaf (Langer 1972).

Leaf bud primordia are formed on alternating sides of the apical meristem (Evans and Grover 1940, Langer 1972, Beard 1973, Dahl 1995). Several leaf primordia are at various stages of development at any one time. The oldest leaf is outermost while younger leaves grow up through existing leaf sheaths (Rechenthin 1956, Beard 1973). Growth of the leaf consists of an increase in cell size (Esau 1960, Dahl 1995). Cell expansion occurs in the region protected by the sheaths of older leaves. When the cells emerge and are exposed to light, expansion ceases and photosynthesis and transpiration start (Langer 1972). New growing leaves receive carbohydrates from roots, stems, or older leaves until the leaf's requirements for growth can be met by the leaf assimilates (Langer 1972).

A few leaf cells are produced by meristematic tissue separated from the apical meristem. These areas are called intercalary meristems and are located at the base of the blade, the base of the sheath and the base of the internode (Esau 1960). The leaf intercalary meristems remain in basal positions which contribute to the grazing tolerance of grass plants by permitting the elevated part of the leaf blade to be removed without stopping growth. Intercalary meristems of leaf blades cease activity by the time the leaf collar is exposed. Once a leaf blade is fully expanded no further growth of that blade is possible (Dahl 1995).

Individual leaves of grass plants are relatively short lived. Young middle-aged leaves are in their prime when the rate of apparent photosynthesis is maximum and the leaves begin exporting assimilates to other parts (Langer 1972). At this point each leaf has its greatest dry weight. Leaf senescence begins to occur shortly after middle age. Senescence begins at the tip, which is the oldest part of the leaf, and spreads downward. As senescence occurs, apparent photosynthesis decreases and export of assimilates stops (Langer 1972). The rate of senescence is influenced by environmental conditions but occurs at about the same rate as leaf appearance. During senescence, cell constituents are mobilized and redistributed to other parts of the plant (Beard 1973). This process causes the leaf to lose weight (Leopold and Kriedemann 1975). Drying leaves are probably neither an asset nor are they detrimental to the plant. The percentage of dryness in a leaf blade is an indicator of the degree of senescence.

Roots grow from the nodes in the crown that are on or below ground. The internodes of the crown associated with roots and rhizomes do not elongate (Dahl 1995). Adventitious roots develop in parenchyma tissue at the nodes just below the internodal intercalary meristem (Langer 1972). It appears that all roots have a limited life span, probably little more than a year at most. Within the root system there is continuous turnover involving senescence, death, decay, and new formation.

Grass plants reproduce by two processes, asexual reproduction and sexual reproduction, which are generally described as vegetative and reproductive phases, respectively. The dates for the initiation of vegetative growth for perennial graminoids are variable with species and local environmental factors, primarily temperature and photoperiod (Langer 1972), and also precipitation (McMillan 1957, Trlica 1977). The early growth is dependent on carbohydrates stored in the roots, rhizomes, or stem bases (Trlica 1977). Vegetative shoots develop from a main shoot by the process of tillering. A tiller is a shoot derived from vertical growth of an axillary bud (Dahl 1995) and is a complete unit with roots, stem, and leaves. There are two types of tillering: intravaginal and extravaginal. Intravaginal tillers grow vertically, close to the main shoot and within the enveloping leaf sheath, and tend to have a tufted or bunch-type growth habit (Dahl and Hyder 1977, Dahl 1995). Extravaginal tillers penetrate the enveloping leaf sheath and grow horizontally away from the main shoot for a distance before vertical growth. This results in the spreading or creeping growth habit of sod-forming plants (Dahl and Hyder 1977, Dahl 1995). If this horizontal growth is below the soil surface it is called a rhizome (Beard 1973), and if it is aboveground it is called a stolon (Dahl 1995). Rhizomes may be either continuous, producing tillers at progressive intervals, or they can be terminal, producing one tiller when the apex turns up and emerges from the soil (Dahl 1995). Stolons have continuous growth and form tillers at progressive nodes (Dahl 1995). All young tillers are dependent on the main shoot for carbohydrates until they have developed their own root systems and mature leaves (Dahl 1995). After the tiller is independent it remains in vascular connection with other tillers (Moser 1977, Dahl and Hyder 1977, Dahl 1995).

Reproductive growth can begin after the plant has met a certain minimum amount of vegetative development. Reproductive initiation is primarily triggered by photoperiod (Roberts 1939, Leopold and Kriedemann 1975, Dahl 1995) but can be slightly modified by temperature and precipitation (McMillan 1957, Leopold and Kriedemann 1975, Dahl and Hyder 1977).

The apical meristem changes from vegetative to reproductive status between the 3.0 and 3.5 leaf stage (Frank 1996, Frank et al. 1997); flower bud primordia develop on the apical meristem, new leaf primordia are inhibited, and no more leaf primordia can be laid down (Esau 1960, Langer 1972). The flower bud primordia develop into an inflorescence with the apical dome becoming the terminal spikelet. Inflorescence initiation cannot be detected without destruction of the plant, but shortly after initiation the developing inflorescence enlarges and swelling of the enclosing sheath is noticeable. This stage of flower stalk development is occasionally referred to as the "boot" stage. This is the first external evidence of flower stalk development. At this point, four or five upper internodes elongate very rapidly along with the attached leaf sheaths. This short phenophase is referred to as head emergence phenophase. The inflorescence reaches near maximum height shortly after emergence, and flowering and fertilization soon follow. Wind promoted cross pollination is the most common process for sexual reproduction in grasses. According to Langer (1972) the flowering phenophase (anthesis) occurs when the lodicules enlarge and separate the lemma and palea. The feathery stigma (female parts) spreads out. The anther filaments elongate and expose the anthers (male parts) which dehisce and liberate pollen. The pollen is moved by wind and may land on the stigmas. About 30-40 hours after pollination, fertilization occurs. Some needlegrasses (*Stipa*) reproduce by self-pollination prior to opening of florets (cleistogamy). Some bluegrass species (*Poa*) can produce seed without fertilization (apomixis). Fertilization (union of male and female gametes) starts the seed development phenophase where the embryo is formed and starch is deposited to form a grain. When the grain is fully formed it can be shed. Some seeds are shed immediately and some remain with the inflorescence all winter unless loosened by wind or physical contact from animals.

The flowering phenophase is triggered by photoperiod. Some grass plants are triggered to flower only after being exposed to day lengths greater than a critical number of hours. These are long-day plants. Most cool-season grasses with the C_3 photosynthetic pathway are long-day plants and reach flowering phenophase prior to 21 June. Short day plants flower only under day lengths shorter than a critical number of hours. Warm-season grasses with the C_4 photosynthetic pathway are short day plants and reach flowering phenophase after 21 June (Leopold and Kriedemann 1975).

Plant populations persist through either sexual or asexual (vegetative) reproduction (Briske and Richards 1995). Vegetative growth is the dominant form of reproduction in semiarid and mesic grasslands (Belsky 1992), including the tallgrass, midgrass, and shortgrass prairies of North America (Briske and Richards 1995). The frequency of true seedlings is low in established grasslands and only occurs during years with favorable moisture and temperature conditions (Wilson and Briske 1979, Briske and Richards 1995), and in areas of reduced competition from older tillers, and when resources are easily available to the growing seedling. Sexual reproduction is necessary for a population to maintain the genetic diversity enabling it to withstand large scale changes (Briske and Richards 1995). Reproductive shoots are adapted for seed production rather than for tolerance to defoliation (Hyder 1972). Grass species that produce a high proportion of reproductive shoots are less resistant to continuous heavy grazing than those species where a high proportion of the shoots remain vegetative (Branson 1953).

Grass plants have developed resistance mechanisms to grazing. Plants that have grazing resistance characteristics have the relative ability to persist in a grazing plant community. Grazing is more than removing herbage from grass plants (Langer 1972). Grazing changes physiological processes in all parts of the plants, it alters the microclimate of the plant community by changing light transmission, moisture relations, and temperature, it changes the soil environment and affects soil organism activity. Grazing resistance characteristics are described in two categories: internal mechanisms and external mechanisms. Internal mechanisms are associated with herbivore-induced physiological processes (McNaughton 1979, 1983). External mechanisms are those involving herbivore-mediated environmental modifications (Briske and Richards

1995). The internal mechanisms are divided into two subcategories: tolerance mechanisms and avoidance mechanisms (Briske 1991). Grazing tolerance consists of mechanisms that facilitate growth following defoliation, including increased meristematic activity and compensatory physiological processes (Briske 1991). Grazing avoidance consists of mechanisms that reduce the probability and severity of grazing, including anatomical and growth form characteristics as well as chemical defences that deter herbivory through the production of secondary compounds which reduce tissue accessibility and palatability (Briske 1991).

Grazing resistance in grass plants is maximized when the cost of resistance approximates the benefits of resistance. Plants do not become completely resistant to herbivores because the cost of resistance at some point exceeds the benefits conveyed by the resistance mechanisms (Pimentel 1988).

Defoliation removes leaf area which immediately disrupts plant growth and photosynthesis. Plants adjust to defoliation by large herbivores with internal tolerance mechanisms during a transition period in which physiological functions are modified, resulting in increased leaf photosynthetic capacity, and increased carbon and nitrogen allocation, which enable defoliated plants to compensate for foliage losses. These internal tolerance mechanisms start immediately following defoliation and occur over a period of several days. Unfavorable environmental conditions at the time of defoliation can limit growth, delaying or slowing plant recovery (Briske and Richards 1995).

Following defoliation of 50% or more of the shoot system, rapidly growing grasses in high fertility environments reduce root growth and elongation, root respiration, and root nutrient absorption (Crider 1955). Root mortality and decomposition may begin within 36-48 hours (Oswalt et al. 1959). Some grass species which are adapted to growing in low fertility environments have increased capacities for root respiration and nutrient absorption rates. These species can maintain root growth, respiration, and nutrient absorption for 48 hours following one severe defoliation, but two or more successive defoliations reduce root growth (Chapin and Slack 1979, Briske and Richards 1995).

The root system continues to function as a carbon sink following defoliation. Soluble carbohydrates within the roots decline as a result of continuous utilization of carbohydrates by root respiration, nutrient absorption, and root growth (Chapin and Slack 1979, Briske and Richards 1995). Very little if any of the root carbon is remobilized to support shoot growth. The carbon source that may be utilized by plants for shoot growth comes from the remaining shoot tissue, stems and rhizomes, and also from alternative substrates which include hemicellulose, proteins, and organic acids (Richards and Caldwell 1985, Briske and Richards 1995). Current photosynthetic carbon from the remaining shoot is preferentially allocated to areas of active shoot meristematic tissue and is more important than carbohydrate reserves for plant growth following defoliation (Briske and Richards 1995). Plants that are severely defoliated depend upon carbohydrate pools to initiate plant growth. Carbon allocation from undefoliated tillers to defoliated tillers increases following defoliation until the defoliated tillers reestablish their own photosynthetic capacity (Briske and Richards 1995). The increased carbon export to defoliated tillers does not occur at the expense of carbon allocations to the root system of undefoliated tillers (Briske and Richards 1995).

Nitrogen pools in the roots and remaining shoot tissue can be mobilized to support shoot growth following defoliation (Briske and Richards 1995). Most of the remobilized nitrogen is allocated from remaining shoot tissue and a small portion is allocated from the root system. The amount of remobilized nitrogen from the remaining shoot is greater when the growth medium is low in available nitrogen than when the growth medium is high in available nitrogen (Millard et al. 1990, Ourry et al. 1990). Nitrate absorption increases at a greater rate in grass plants grown in low fertility than high fertility environments within 8 hours after defoliation (Macduff et al. 1989).

Defoliated plants increase photosynthetic rates of remaining foliage (Briske and Richards 1995). This compensatory photosynthesis can be induced by changes in light intensity and quality that result from grazing modifications in the microhabitat and by modifications of physiological functions which are caused by the indirect effects that result from increased root-shoot ratio, and are mediated by cytokinins and other signals produced in the root (Briske and Richards 1995). These changes appear to affect leaf development and aging such that the photosynthetic apparatus is rejuvenated and the leaf senescence rate is inhibited or reduced, increasing the lifespan of leaves. (Briske and Richards 1995). Remaining mature leaves on defoliated plants frequently develop increased leaf mass per unit area within 1-14 days after defoliation (Briske and Richards 1995). Leaves exhibiting compensatory photosynthesis after defoliation may have higher dark respiration rates which is characteristic of leaves with higher protein contents (Atkinson 1986).

The growth rate of replacement leaves and shoots is increased following defoliation. The rate of leaf area expansion following defoliation is determined by interactions among meristem type, environmental variables and resource availability (Briske and Richards 1995). Growth is most rapid from intercalary meristems, intermediate from apical meristems, and slowest from axillary buds (Briske and Richards 1995). Expanding leaves tend to grow longer on defoliated plants than on undefoliated plants. The photosynthetic rate of the regrowth leaves is higher than that of same age foliage on undefoliated plants. Enhanced leaf and tiller growth rates usually persist for only a few weeks following defoliation, and are not consistently expressed in all environmental conditions or phenological stages within the growing season.

Vegetative growth from axillary buds can be manipulated by defoliation management at some phenological growth stages by reduction of influence from apical dominance. Apical dominance is the physiological process by which the apical meristem from a lead tiller exerts hormonal regulation over axillary bud growth (Briske and Richards 1995). Auxin, which is a growth inhibiting hormone, is produced in the apical meristem and young developing leaves and interferes with the metabolic function of cytokinin, a growth hormone, in the axillary buds. Auxin does not directly enter the axillary buds and its indirect effects are not thoroughly understood (Briske and Richards 1995). Defoliation can influence tillering from axillary buds by temporarily reducing the production of the blockage hormone, auxin, within the meristem and young developing leaves (Briske and Richards 1994). This reduction of plant auxin in the lead tiller allows either for cytokinin synthesis in the roots, or in the crown, or for its utilization in axillary buds, which stimulates the development of vegetative tillers (Murphy and Briske 1992, Briske and Richards 1994). Partial defoliation of young leaf material reduces the hormonal affects of apical dominance by the lead tiller, allowing some secondary tillers to develop from the previous year's axillary buds. Secondary tillers can develop without defoliation manipulation after the lead tiller has reached anthesis phenophase, but usually only one secondary tiller develops from the potential of five to eight buds because this secondary tiller hormonally suppresses additional axillary bud development by apical dominance. When the lead tiller is partially defoliated at an early phenological growth stage, several axillary buds can develop subsequently into secondary tillers. Apparently, no single secondary tiller is capable of developing complete hormonal apical dominance following defoliation of the lead tiller at this time. Some level of hormonal control from the older axillary buds still suppresses development of some of the younger axillary buds (Manske 1996). With our present level of knowledge of this mechanism, we are unable to achieve the full potential of all axillary buds developing into secondary tillers.

Stimulation of tillering by defoliation is not consistent through the growing season and is influenced by stage of phenological development, environmental variables, and frequency and intensity of defoliation. Defoliation alters the timing or seasonality of tiller recruitment and may not increase the total number of tillers over the long-term in many native range grasses (Briske and Richards 1995).

The axillary buds which have most recently matured grow out to form tillers, even though older buds may exist on the crown (Busso et al. 1989). Axillary buds survive as long as the parental tiller remains alive. The longer axillary buds remain inhibited the less likely they are to form tillers (Mueller and Richards 1986).

Interaction between the physiological stage of plant development and plant defoliation is not completely understood. Defoliation during early vegetative growth exerts a negligible or slight stimulatory effect on tillering (Olson and Richards 1988, Vogel and Bjugstad 1968). Defoliation during vegetative growth promotes tiller recruitment in some grasses to a greater extent than during any other phenological stage. Defoliation at the time of culm elongation but prior to inflorescence emergence, stimulates tillering in several grass species (Olson and Richards 1988). Defoliation at the boot stage suppresses tillering in some warm-season grasses which are stimulated to tillering during the inflorescence emergence stage (Vogel and Bjugstad 1968). Apical meristem removal by defoliation increases tillering in several warm-season grasses (Richards et al. 1988, Murphy and Briske 1992) but does not stimulate tillering in some cool-season grasses (Branson 1956, Richards et al. 1988).

Tiller development decreases with increasing frequency and intensity of defoliation. Low levels of grazing also reduce tiller densities by decreasing tiller development and increasing tiller mortality through shading (Grant et al. 1983). The optimal defoliation intensity will vary with species, stage of phenological development, and associated environmental variables (Langer 1963). Grazing some native bunchgrass populations decreases individual plant basal area and increases total plant density (Butler and Briske 1988). Severe grazing may reduce total basal area and tiller numbers (Olson and Richards 1988).

Tillers recruited early in the growing season frequently become florally induced and terminate their life cycle during the same growing season, while tillers recruited later in the season frequently over-winter and resume growth the subsequent growing season (Briske and Richards 1995). The longevity of these late tillers generally does not exceed two complete growing seasons (Langer 1956, Butler and Briske 1988). Tiller longevity for grasses and sedges is greater at northern latitudes than in southern latitudes (Briske and Richards 1995). Plant longevity of some major northern grass species may range from 27 to 43 years (Briske and Richards 1995).

Internal avoidance mechanisms enhance some grass species ability to deter herbivory by the production of secondary compounds for chemical defence and the deposition of mineral silica in epidermal cells. Other internal avoidance mechanisms reduce plant tissue accessibility by growth morphology. Both grazing and mowing can function as selection pressure on grass plant growth morphology, causing growth forms to change and be low and close to the ground. This genetically based change in growth form can occur in less than 25 years (Briske and Anderson 1992). The grazing-induced growth forms are characterized by a large number of small tillers with reduced leaf numbers and blade areas (Briske and Richards 1995). This growth form is better able to avoid grazing because less biomass is removed and a greater number of meristems remain to facilitate growth.

Grass plants exhibit two strategies of culm elongation, described as short or long shoots. Short shoots do not have significant internode elongation during vegetative growth, and the apical meristem remains below cutting or grazing height, continuing to produce new leaves until it changes to reproductive status and elongates the flowering culm (Dahl 1995). Short shoots that remain vegetative may have the apical meristem vegetatively active for more than one growing season (Dahl 1995). Long shoots elevate the apical meristem by internode elongation while still in vegetative status (Dahl 1995). Many grass species with long shoots are stimulated to increase tillers by moderate defoliation prior to flowering (Richards et al. 1988). Long shoot plants are nearly always decreased in pastures that are heavily grazed continuously (Branson 1953).

Long-term ungrazed grass plants shift to erect growth forms with a smaller number of large tillers with large leaf areas because of the increase in mulch accumulation and shading (Briske and Richards 1995). Root growth is reduced because they are very sensitive to reduction in light intensity suffered by the leaves. Reduced light levels or shading has more serious effects on roots than on shoots (Langer 1972).

External mechanisms contribute to compensatory grass growth following defoliation. Grazing removes some of the aboveground herbage and increases solar radiation to the remaining leaf tissue. Defoliation improves plant water status due to an increase in root-shoot ratio and reduction of the transpiration surface. Increasing the root-shoot ratio also increases nutrient supply to remaining tissue.

Another important external mechanism which is influenced by defoliation of grassland plants is the symbiotic activity of soil organisms within the rhizosphere (Manske 1996). The rhizosphere is that narrow zone of soil surrounding living roots of perennial grassland plants where the exudation of sugars, amino acids, glycosides, and other compounds affects microorganism activity (Curl and Truelove 1986, Whipps 1990, Campbell and Greaves 1990). Bacterial growth in the rhizosphere is stimulated by the presence of carbon from the exudates (Elliott 1978, Anderson et al. 1981, Curl and Truelove 1986, Whipps 1990). Protozoa and nematodes graze increasingly on the increased bacteria (Curl and Truelove 1986), and accelerate the overall nutrient cycling process through the "fast" pathway of substrate decomposition as postulated by Coleman et al. (1983). The activity of the microbes in the rhizosphere increases the amount of nitrogen available for plant growth (Ingham et al. 1985a and b, Clarholm 1985, Allen and Allen 1990). The presence of vasicular-arbuscular mycorrhizal (VAM) fungi enhances the absorption of ammonia, phosphorus, other mineral nutrients, and water (Moorman and Reeves 1979, Harley and Smith 1983, Allen and Allen 1990, Box and Hammond 1990, Marschner 1992). Rhizosphere activity can be manipulated by defoliation at early phenological growth stages when a higher percentage of the total nitrogen of the plant is in the aboveground parts and a higher percentage of the total carbon of the plant is in the below ground parts. At that time, partial defoliation disrupts the plant's carbon to nitrogen ratio, leaving a relatively high level of carbon in the remaining plant. Some of this carbon is exuded through the roots into the rhizosphere in order to readjust the carbon-nitrogen ratio. Bacteria in the rhizosphere are limited by access to simple carbon chains under conditions with no defoliation (Curl and Truelove 1986). The rhizosphere bacteria increase in activity in response to the increase in exuded carbon under conditions with defoliation (Lynch 1982, Ingham et al. 1985a and b). The increase in activity by bacteria triggers increases in activity in other trophic levels of the rhizosphere organisms (Curl and Truelove 1986). This ultimately increases available nutrients for the defoliated grass plant (Ingham et al. 1985a and b, Clarholm 1985). During middle and late phenological stages of growth, carbon and nitrogen are distributed more evenly throughout the plant. Defoliation at that time does not remove a disproportionate amount of nitrogen, and very little or no carbon is exuded into the rhizosphere. Soil water levels generally decrease during middle and late portions of the grazing season and also limit rhizosphere organism activity levels (Curl and Truelove 1986, Bazin et al. 1990).

Management by defoliation with herbivores has the greatest beneficial effects if planned to stimulate two mechanisms: vegetative tillering from axillary buds and activity of symbiotic soil organisms in the rhizosphere. The phenological growth stages when these two mechanisms can be manipulated are the same, between the third leaf stage and the flowering phenophase. Defoliation at other phenological stages has little beneficial stimulatory effect on grass growth.

Defoliation management that is designed to enhance sexual reproduction through seed production does not improve the prairie ecosystem. Seedlings contribute very little to plant production, and the energy and resources used in seed production could be manipulated into vegetative tiller production, which could improve the prairie ecosystem.

Fall and winter defoliation have the potential to greatly reduce grass density and production the following year because late stimulated tillers remain viable over winter and cool-season species initiate tillers the fall before. Defoliation of these tillers reduces their contributions to the ecosystem the following summer.

Defoliation management by livestock can be used to sustain healthy native prairie ecosystems when the biological processes developed by grass plants are considered and understood. Sustainable prairie management requires that grass plant needs and biological processes have the highest priority in the planned management strategy. Management strategies with different goals as the prime objectives may have short term benefits but can not be sustained for the long term if their goals are adverse to grass biology.

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THE EFFECT OF CATTLE REMOVAL ON BIODIVERSITY IN GRASSLANDS NATIONAL PARK

S.J. McCanny

Western Canada Service Centre, Parks Canada, 457 Main Street, Winnipeg, Manitoba R3B 3E8

P. Fargey

Grasslands National Park, P.O. Box 150, Val Marie, Saskatchewan S0N 2T0

G.C. Sutter

Department of Biology, University of Regina, Regina, Saskatchewan S4S 0A2

A. Finnamore

Provincial Museum of Alberta, 12845 102 Avenue, Edmonton, Alberta T5N 0M6

Abstract: Since its formation, cattle have been excluded from Grasslands National Park. Grazing has long been considered to promote plant diversity by suppressing dominant grasses and to have important effects on animal diversity through its effects on the physical structure of the vegetation. We examined the effect of the no-grazing policy on the diversity of vascular plants, songbirds and large insects in native grasslands. Seven pairs of 12 ha sites were chosen in and around the park to represent different combinations of slope and soil texture. One site from each pair had not been grazed for 4 to 10 years. No significant effects of grazing were found in the number of species at a single location (diversity) or in the number of new species found along a transect (diversity). Exotic species were uncommon in both treatments. The grazed and ungrazed communities differed in composition, however. Without cattle, the plant communities were 81% similar to grazed communities and tended to favor needle and thread and northern wheat grasses as well as hairy golden aster and prairie crocus over dryland sedges and prairie coneflower. The bird communities were 67% similar. Baird's sparrow and Sprague's pipit were found more commonly on ungrazed prairie while chestnut-collared longspur and horned lark were more likely to be found on grazed land. The carabid beetle communities were 64% similar. *Microlestes linearis* showed a distinct preference for grazed prairie while *Amara obesa* was more likely to be found on ungrazed land. The regional (or γ) diversity of the current landscape was calculated for all taxa. It cannot be maximized without both grazing and long term rest. Ungrazed prairie has valuable conservation properties and should be represented in regional prairie ecosystems.

GRAZING AS A MANAGEMENT TOOL ON THE MANITOBA TALL GRASS PRAIRIE PRESERVE

Gil Lahaie

Manitoba Agriculture, 600 1495 St. James Street, Winnipeg, Manitoba R3H 0W9

Abstract: Approximately 5000 acres of remnant tall grass prairie in southeastern Manitoba is maintained and managed in the Manitoba Tall Grass Prairie Preserve. Aspen encroachment is the most significant threat to the grassland sites on the Preserve. Fire has been the main management tool to control aspen and maintain existing grasslands. In 1993-94, the Critical Wildlife Habitat Program and the Stuartburn-Piney Agricultural Development Association secured funding under the Canada-Manitoba Agreement on Agricultural Sustainability for a 4 year project to determine the impact of managed grazing on the condition of the prairie, and to demonstrate grazing management techniques to area beef producers. A 3 pasture, twice-over grazing system has been utilized for 3 years on the site. Preliminary results point to positive vegetation shifts on sites grazed twice during the season as compared to ungrazed sites. Livestock weight gains from managed grazing have also been promising. Discussions are occurring with respect to the continuation of the project, as well as including grazing as a management tool on other sites within the Preserve.

INTRODUCTION

Approximately 2200 hectares (5000 acres) of remnant tall grass prairie in south eastern Manitoba are being maintained and managed under the Manitoba Tall Grass Prairie Preserve. Located south of Winnipeg approximately 4 miles north of the Canada-United States border, it includes the largest remaining areas of tall grass prairie now found in Manitoba. The majority of the lands included in the Preserve are owned by either the Nature Conservancy of Canada or the Province of Manitoba and are managed by the Critical Wildlife Habitat Program (CWHP), with input from a local advisory committee.

To date, fire has been the main management tool, with the objectives being stimulation of warm season grasses and the suppression of encroachment of woody species. Biological control of exotic weeds such as leafy spurge (*Euphorbia esula* L.) and St. John's Wort (*Hypericum perforatun* L.) has been investigated, as has individual tree treatment for aspen (*Populus tremuloides* Michx.) by girdling or lance-injected glyphosate.

In 1993, the CWHP became aware of some successful long term research conducted by Dr. Llewellyn Manske of the Dickinson Research Extension Center in North Dakota on grazing of tall grass prairie under a twice-over grazing system. The basis of the success of the twice-over system was attributed to the stimulative effect of partial defoliation of grass plants during the 3 leaf to flowering stage. Partial defoliation during that period reduces of the apical dominance of the lead tiller allowing the earlier development of more secondary tillers. Another effect is the acceleration of microbial activity in the rhizosphere, resulting in an increase in the availability of nutrients for the defoliated plants.

In an attempt to assess the possible benefits of the twice-over grazing system as a tool to manage the lands in the Tall Grass Prairie Preserve, in 1993-94, the CWHP and the Stuartburn-Piney Agricultural Development Association (SPADA), a local agricultural producer group, secured funding under the Canada-Manitoba Agreement on Agricultural Sustainability, (CMAAS). The objectives of the 4 year project were:

a) to develop, in cooperation with local producers and SPADA, a rotational grazing demonstration project that illustrates the benefits of integrating sound agricultural and wildlife management practices, and
b) to develop extension materials and activities to interpret the ecology of native grasslands and prairie management techniques.

SITE SELECTION

The site selected for the Tall Grass Prairie Grazing management Project was three quarter sections on section 29-01-6EPM in the Gardenton area. The vegetation on the 195 ha site consists of approximately 105 ha of tall grass prairie, 63 ha of aspen-oak woodland and 27 ha of sedge meadows. A preliminary vegetation study had found 95 native plant species, including a population of the provincially endangered small white lady's slipper (*Cypripedium candidum* Muhl.). This site had not been grazed for a number of years and was in what could be termed good condition.

In the 1994 the site was burned to remove accumulated litter. The area was fenced and cross-fenced into 3 pastures using high tensile smooth wire and a centrally located holding and watering facility, along with a well, were constructed. The power sources for the electrified fence and the water pump are batteries recharged by solar panels. Four 15m x 15m exclosures for vegetation monitoring were also established. The site was grazed during 1995, 1996, and 1997, and livestock performance has been monitored. As well, the response of the prairie has been monitored.

LIVESTOCK PERFORMANCE

1995

The site was stocked with 64 yearling steers with an average weight of approximately 350 kg. (786 lbs.) on June 8. Thirty of the steers were implanted with a growth hormone at turnout. The total liveweight on pasture on June 8 was 22,460 kg.(50,309 lbs.). The steers were grazed for 15 days on each of the 3 pastures during the initial grazing period, followed by 30 days on each pasture during the second grazing. Cattle were reweighed on August 24, September 18, and at removal on October 10. The length of the grazing season was 122 days. The total weight off pasture was 26,980 kg. (60,438 lbs.) The performance of the steers as expressed in average daily gain per head is shown in Table 1. Summarizing the results, although the average daily gains per head for the grazing season were 1.44 lbs./head/day and 1.13 lbs./head/day for the implanted and control groups respectively, the actual performance varied considerably from these averages at intervals during the growing season. The poor performance for the September 18-October 10 period led us to conclude that the prairie could not provide the high quality diet required by this class of livestock at the late stages of the growing season and that some changes to the rotation pattern should be implemented.

1996

Eighty-seven yearling heifers averaging 255 kg. (574 lbs.) were turned out to pasture on June 12. Total liveweight on pasture on June 12 was similar to the previous year at 22,185 kg. (49,700 lbs.). Due to the "skitterish" nature of these heifers and difficulties encountered in weighing, the turnout weights are the only weights we had confidence in, and no performance data is available for 1996. The rotation pattern was modified in 1996 to provide for a 12 day initial grazing followed by a 22-24 day second grazing. Problems were also encountered in keeping to this schedule. The heifers were removed from the pasture on September 12 for a 93 day grazing season which was somewhat short of our target.

1997

We decided to utilize cow-calf pairs for 1997. There were two reasons for this: the assumption that cow-calf pairs would be easier to manage on pasture and the fact that the nutritional quality of native rangeland was better suited to cow-calf pairs than yearlings. Thirty-three pairs and a bull were turned out on June 7. Total liveweight on pasture on June 7 was 24,690 kg. (55,309 lbs.). The cows and calves were re-weighed at intervals during the grazing season, on July 11, August 5, August 28, and at removal on September 22. The rotation pattern again provided for an initial grazing period of approxi-

Table 1. Performance of yearling steers on tall grass prairie - 1995.

	Average daily gain, lbs./head	
Season performance (122 days)	implanted	1.44 lbs.
	control	1.13 lbs.
At intervals:		
June 8-Aug. 24	implanted	1.89 lbs.
	control	1.43 lbs.
Aug. 25-Sept. 18	implanted	1.49 lbs.
	control	1.16 lbs.
Sept. 19-Oct. 10	implanted	-0.5 lbs.
	control	+.16 lbs.

Table 2. Performance of cow-calf pairs on tall grass prairie - 1997.

	Average daily gain, lbs./head	
Season performance	calves	2.57 lbs.
(108 days)	cows	-.13 lbs.
At intervals:		
June 7-July 11	calves	3.20 lbs.
	cows	1.40 lbs.
July 12-Aug. 5	calves	2.43 lbs.
	cows	-1.54 lbs.
Aug. 6-Aug. 28	calves	2.55 lbs.
	cows	+.50 lbs.
Aug. 29-Sept. 22	calves	1.70 lbs.
	cows	1.57 lbs.

mately 12 days, followed by a second grazing period of 24 days, and for a 108 day grazing season. Performance of the cows and calves expressed in average daily gain per head is shown in Table 2. The average season-long gain of 2.57 lbs./head/day for the calves can be considered a reasonable rate of gain. However, there were some variations during some intervals during the season and a significant drop in rate of gain during the last interval. This will require further investigation. We had expected a somewhat better cow performance than we obtained, and this too will require further investigation.

VEGETATION RESPONSES

The 4 exclosures were subdivided into 3 treatments to measure differences in vegetation response from different exposures to grazing. The treatments reflect: a) no exposure to grazing, b) grazed once during the initial rotation only, and c) grazed twice. Species composition was measured in June 1995, August 1995, August 1996, and August 1997 using the 10 pin point frame method. Productivity and biomass were sampled by clipping five .25 m x .25 m quadrats to ground level in August of each year. The purpose of this project is to determine if moderate grazing through a 3 pasture twice-over system can enhance tall grass prairie. Enhancement can be defined as either maintaining a favourable species composition balance, and/or influencing species composition in a certain direction. A change in species composition of a prairie type under moderate use, especially if it was in good condition initially, is a relatively slow process. This site has been grazed for only 3 years, and the vegetation response data is preliminary. Figure 1 shows the relative percent cover of bare ground in the 3 treatments over the three years. As would be expected, the grazed twice treatment shows the highest percentage bare ground, but this is still within an acceptable range. Figure 2 shows the relative percentage cover of litter. Percentage cover of litter is slightly lower on the grazed twice treatment in comparison to the grazed once and ungrazed treatments. Big Bluestem (*Andropogon gerardi* Vitman) appears to benefit from moderate grazing as evidenced by its slightly higher percentage cover in the twice grazed areas in Figure 3. Grazing does not appear to influence Indian Grass (*Sorghastrum nutans* [L.] Nash), Figure 4, and the relatively high percentage cover measurements in 1995 are likely the result of stimulation of Indian Grass from the 1994 burn. Figure 5 shows the response of small white lady's slipper to grazing. The higher number of plants in both grazing treatments would indicate that grazing benefits this

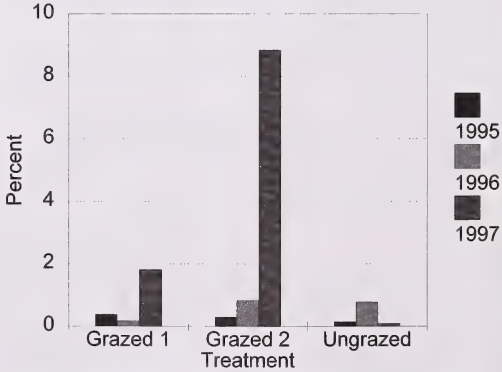

Figure 1. Percent cover of bare ground under three grazing treatments.

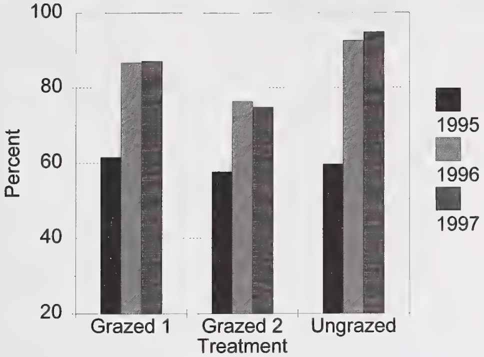

Figure 2. Percent cover of litter under three grazing treatments.

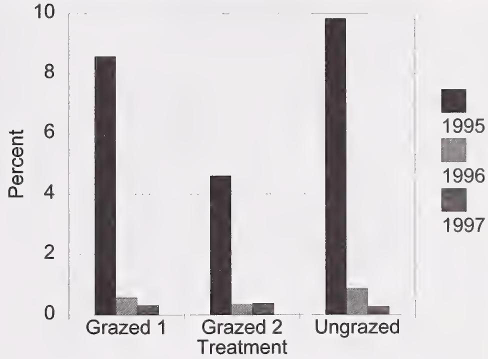

Figure 4. Percent cover of Indian grass under three grazing treatments.

plant, although the benefit is likely from the impact of reduced shading in the grazed areas.

DISCUSSION

Although the vegetation response data is preliminary, we believe that we see a trend towards some favourable changes in the condition of the tall grass prairie as a result of implementing the 3 pasture, twice-over system. In regards to the livestock aspect, the 3 pasture twice-over system can result in reasonable rates of gain for cow-calf producers. Since the optimum length of grazing season on this prairie appears to be 100-110 days, a grazing management program utilizing tall grass prairie should also include cool season tame pasture to extend the grazing season in both spring and fall. Funding under CMAAS expired at the end of 1997. The project will continue for at least 3 years through in kind funding from the partners and revenues generated by grazing fees. Further investigation should determine how effective managed grazing can be to manage other lands in the Preserve.

ACKNOWLEDGMENTS

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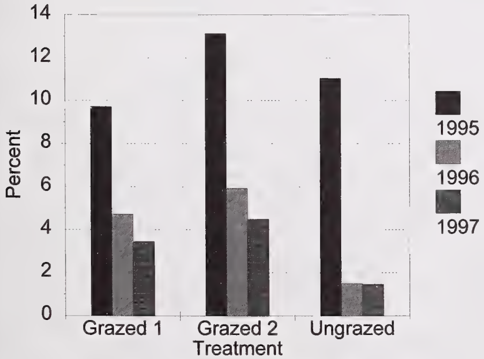

Figure 3. Percent cover of big bluestem under three grazing treatments.

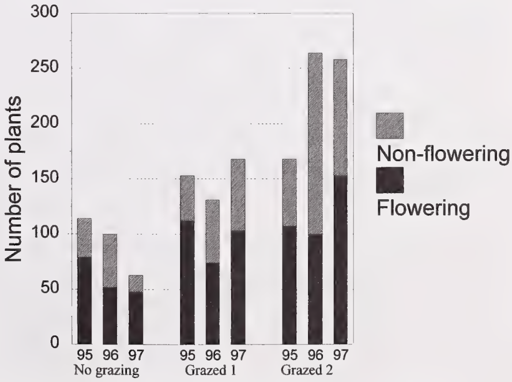

Figure 5. Number of small white lady's slippers under three grazing treatments.

CONSERVATION OF MIXED GRASS PRAIRIE IN MANITOBA

Janet Moore

Critical Wildlife Habitat Program, Box 24, 200 Saulteaux Crescent, Winnipeg Manitoba R3J 3W3

Abstract: Mixed grass prairie once covered approximately 24 million hectares in Canada. Today estimates suggest that less than 25% of this community remains in its native state. The remaining habitat is important to maintain populations of many species of wildlife, and instrumental in preserving biodiversity. In 1996, a mixed grass prairie conservation project was initiated under the Critical Wildlife Habitat Program to determine the amount of mixed grass prairie remaining in Manitoba. The goal of the project is to conserve the native mixed grass prairie ecosystem by identifying remaining parcels of mixed grass prairie in Manitoba and promoting agricultural activities that incorporate wise land stewardship. This is being achieved by systematically surveying the known range of mixed grass prairie in Manitoba and developing demonstration projects as part of a multi-agency partnership coordinated by the Critical Wildlife Habitat Program. Preliminary results from the survey show that the four major threats to mixed grass prairie are cultivation, invasion of exotic plants, aspen encroachment, and inappropriate grazing regimes. Several local grazing projects are being established in cooperation with Manitoba Conservation Districts to help demonstrate sustainable grazing practices. In addition to the grazing demonstrations, an extension program is being developed in cooperation with local conservation groups to increase public awareness of the mixed grass prairie ecosystem.

INTRODUCTION

Mixed-grass prairie once covered approximately twenty-four million hectares in Canada from Alberta to southwestern Manitoba. Today, less than 25% of this community remains in its native state (World Wildlife Fund Canada 1989), generally in areas unsuitable for cultivation. Mixed-grass prairie occurs in areas that receive between 25 and 50 cm of precipitation annually and where soils are sandy or well-drained. Typical species include grasses such as little bluestem (*Andropogon gerardi*), needle grasses (*Stipa* spp.) and blue grama (*Bouteloua gracilis*), and wildflowers such as prairie crocus (*Anemone patens*), dotted blazing star (*Liatris punctata*), prairie coneflower (*Ratibida columnifera*), purple cone flower (*Echinacea angustifolia*) and prairie lily (*Lilium philadelphicum*). The amount of mixed-grass prairie has decreased dramatically in the last 200 years. The remaining habitat is vitally important to maintain populations of many species of wildlife and is instrumental in conserving biodiversity.

Three initiatives are being undertaken in Manitoba in response to the loss of this ecosystem. These include a survey to identify and rank the remaining native prairie, an awareness program to promote prairie stewardship and grazing demonstration projects to encourage wise land use practices.

MIXED-GRASS PRAIRIE INVENTORY

In 1996, the Critical Wildlife Habitat Program (CWHP), an integrated cooperative program, administered by Manitoba Natural Resources, embarked on an inventory to identify and rank the remaining areas of mixed-grass prairie in Manitoba. This inventory continued in 1997 and additional field work is planned for 1998.

The first step in this project was to compile existing information on mixed-grass prairie in Manitoba from available sources. The second step was to systematically survey the known range of mixed-grass prairie to determine the extent and quality of the remaining parcels.

Several surveys for mixed-grass prairie have been undertaken in Manitoba over the past ten years, including surveys by Prairie Farm Rehabilitation Administration (PFRA), Manitoba Natural Resources, and the CWHP. Information from these surveys was used to help identify possible locations of mixed-grass prairie in Manitoba. Landsat satellite imagery, forest inventory maps, soil surveys, and referrals by landowners were also used to determine which areas in southwestern Manitoba had the potential to contain mixed-grass prairie. In 1996, the Oak Lake and Miniota regions were selected as target areas for in depth inventories. These areas were selected

Table 1. Mixed-grass prairie inventory results - 1996 and 1997.

Prairie Grade	Number of sites		Number of hectares		Total Hectares
	1996	1997	1996	1997	
B	15	30	811	1,122	1,933
C	71	92	1,951	2,673	4,624
D	114	80	4,658	3,489	8,147
TOTAL	200	202	7,420	7,284	14,704

because large blocks of prairie were known to occur and little information was available on these sites. In 1997, an area surrounding the Assiniboine Delta in the Carberry-Spruce Woods area was surveyed.

Each parcel of land surveyed was divided into communities using the list of natural community descriptors described by the Manitoba Conservation Data Centre (CDC) (Greenall 1996a); each community was then graded using the CDC grading guidelines (Greenall 1996b). Under these guidelines, a grade of C or higher is considered a good quality community with the potential to improve over time with proper management. A grade of D indicates poor quality sites that would require extensive management to improve.

Results

In 1996, 200 sites were inspected, and in 1997, 202 sites were inventoried. Table 1 outlines the quality of the prairie found on the surveyed sites.

As a means of grouping similar prairies together, sites were categorized by soil types (see Table 2). During the 1996 field season, the mixed-grass prairie inventoried fell mainly into two soil associations, Souris and Oxbow. During the 1997 field season, the mixed-grass prairie inventoried fell mainly into four soil associations: Miniota, Stockton, Marringhurst, and Oxbow.

The Carroll association occurs southeast of Brandon and west of Brandon to Virden. It includes fine-to medium-textured soils developed on lacustrine sediments. The drainage of this soil type is generally good and the soils have high natural fertility, with isolated alkalized areas with lower fertility (Ellis and Schafer 1943). This association is generally cultivated, so very little mixed-grass prairie remains in the soil association.

The Marringhurst association is located in scattered areas adjacent to the Assiniboine River valley. The largest area of this association occurs at the junction of the Qu'Appelle and Assiniboine rivers near St. Lazare.

Table 2. Soil associations of the mixed-grass prairie inventory sites.

Soil Association	1996		1997	
	# of sites	Hectares	# of sites	Hectares
Carroll			6	110
Marringhurst	4	516	24	888
Miniota			56	2,763
Other	5	117	29	1,043
Oxbow	43	1,408	20	1,376
Pipestone	6	344		
Souris	139	4,989	6	124
Stockton			61	980
Tiger Hills	3	46		
TOTAL	200	7,420	202	7,284

The Marringhurst association soils are generally coarse sandy loam (Ehrlich et al. 1956). Almost all of the Marringhurst deposits are well- to excessively-drained. Typical species of this association include blue grama, needle-and-thread grass (*Stipa comata*), June grass (*Koeleria cristata*), prairie crocus, three-flowered avens (*Geum triflorum*), northern bedstraw (*Galium septentrionale*), prairie sagewort (*Artemesia frigida*), and many-flowered aster (*Aster pansus*). This soil association is generally used for pasture because of its susceptibility to drought and wind erosion (Ehrlich et al. 1956).

The Miniota association occurs in patches near the settlements of Miniota and Shilo. These soils consist of sandy loam soils developed on sand and coarse sand. Drainage is good over most of the area (Ehrlich et al. 1956). Typical native plants of this soil association include blue grama, sand dropseed (*Sporobolus cryptandrus*), little bluestem, needle-and-thread grass, June grass, prairie sagewort, creeping juniper (*Juniperus horizontalis*), three-flowered avens, beautiful sunflower (*Helianthus maximiliani*), thimbleweed (*Anemone cylindrica*), and prairie crocus. Miniota soils have limited agricultural fertility and are subject to severe wind erosion when cultivated. The soils of this association are generally best used as pasture land (Ehrlich et al. 1957).

Oxbow association soils occur on the upland plain along the Manitoba-Saskatchewan border west of the Assiniboine river and glacial Lake Souris basin. These soils are loam to clay loam (Ehrlich et al. 1956). The topography is gently sloping and drainage is subject to local conditions. Typical species of this soil type include blue grama, little bluestem, June grass, needle and thread-grass, dotted blazing star, prairie sage, low goldenrod (*Solidago nemoralis*), thimbleweed and beautiful sunflower. These soils are usually not suited to cultivation and are used for pasture or, where topography permits, hay.

The Souris association occurs in southwestern Manitoba from just north of Oak Lake south to the United States border near the community of Lyleton. The association consists of fine sandy textured soils developed on sandy lacustrine deposits. Drainage is impeded, except in areas of duned sand; sand dunes occur along the eastern two-thirds of the region (Ehrlich et al. 1956). Typical plants include little bluestem, needle-and-thread grass, switch grass (*Panicum virgatum*), prairie coneflower, many-flowered aster, thimbleweed, prairie sage, western snowberry (*Symphoricarpos occidentalis*) and wild licorice (*Glycyrrhiza lepidota*). The duned phase of this soil type is vegetatively distinct from the other phases. Two rare species, sand bluestem (*Andropogon hallii*) and hairy prairie clover (*Petalostemum villosum*), were found throughout most of the sites in the duned phase. Where drainage and topography permits, the land is cultivated into grain crops, but the majority of the region in used for livestock grazing or forage crops (Ehrlich et al. 1956).

The Stockton association occurs just east of Neepawa south to Glenboro. This association has sandy soils with good to excessive drainage. The Stockton soils have low fertility and are susceptible to wind erosion. The texture of this soil type varies from sand to loamy fine sand and includes extensive areas of sand dunes (Ehrlich et al. 1957). Typical species include little bluestem, blue grama, needle-and-thread grass, sand reed grass (*Calamovilfa longifolia*), sand dropseed, three-flowered avens, prairie crocus, dotted blazing star, beautiful sunflower, hairy golden aster (*Chrysopsis villosa*), purple coneflower, white spruce (*Picea glauca*), and creeping juniper. Historically, these characteristics combined with low water-retention capacity and droughtiness have limited the agricultural value of much of this association (Ehrlich et al. 1957). Recently, irrigation has increased the agricultural value of this land and its vulnerability to cultivation.

Threats to Mixed-grass Prairie

Four major threats to Manitoba's mixed-grass prairie were identified in this survey, including: inappropriate grazing management, cultivation, exotic species invasions and aspen (*Populus tremuloides*) encroachment. Inappropriate grazing management is one of the most pervasive and serious threats to the long-term survival of the mixed-grass prairie in southwestern Manitoba. Many sites are grazed season-long from the middle of May until September. This has resulted in modified species compositions and an increase in shrubby species.

Although much of the mixed-grass prairie region in Manitoba has been cultivated, this practice still continues to be a threat to many of the remaining areas. In 1996, two prairie sites inspected in previous inventories were found to have been cultivated. Six other sites totalling 413 hectares were shown as grassland on 1995 Landsat imagery, but were cultivated by the summer of 1996. In 1997, cultivation was found to be the greatest threat to mixed-grass prairie in the Carberry-Brandon area. The agricultural value of the land has increased, due to increased irrigation from the underlying aquifer. Many pastures that were good quality mixed-grass prairie have been broken in the last few years in Manitoba.

A number of exotic species such as smooth brome (*Bromus inermis*), sweet clover (*Melilotus* spp.) and leafy spurge (*Euphorbia esula*) are invading native prairie sites. Most of the mixed-grass prairies inventoried in the summer of 1996 and 1997 have invasive non-native species present to some extent. Large infestations of leafy spurge occur throughout the Brandon-Shilo area and the Lauder sand hills.

Trembling aspen and other woody species are increasing because of fire suppression. Most of the prairie sites inventoried in the Oak Lake-Miniota region and many in the Carberry-Brandon area are impacted by aspen encroachment. Studies of aerial photos from 1946 to 1994 in the Rural Municipality of Victoria indicated that over 22% of the prairie had been lost to aspen encroachment in 1004 ha of Crown land (Rangeland Manager 1997).

MIXED-GRASS PRAIRIE EXTENSION PROGRAM

In response to the growing concern about the loss of prairie in Manitoba, the Seton Centre in Carberry initiated a mixed-grass prairie extension project in 1997. Cooperators include the CWHP, Manitoba Natural Resources, Manitoba Habitat Heritage Corporation, Environment Canada, Manitoba Agriculture and Ducks Unlimited Canada.

The goals of this project are to increase awareness of the importance of mixed-grass prairie, to enable people to make informed choices and to minimize future losses of this ecosystem. The objectives are to develop a broad based public awareness initiative, including a private land stewardship program, that can be delivered in the mixed-grass prairie region of Manitoba and to initially deliver this program in one target area, the Carberry-Shilo area, where large remnants of prairie are still found but threats of cultivation are increasing. This private land stewardship program will be similar to the Native Prairie Stewardship Program in Saskatchewan, which works with private landowners to voluntarily protect remnant prairies.

The project is geared towards several target audiences including user groups of the resource, landowners, the general public, schools, conservation groups, and policy makers. Activities include the development of: fact sheets; news releases; workshops; slide shows to be delivered to municipal councils, planning committees, schools and the general public; school programs; displays; a video; and an interpretive program.

GRAZING DEMONSTRATIONS

Recent discussions among agencies concerned with the preservation and maintenance of the remaining native prairie in Manitoba, including Ducks Unlimited Canada, Manitoba Agriculture, PFRA, the Manitoba Habitat Heritage Corporation, Environment Canada, and Manitoba Natural Resources, indicated a need to encourage landowners to manage their native pastures in ways that conserve them in the long term. Continuous season long-grazing is the normal practice in Manitoba. The majority of producers base their grassland management on livestock numbers, not the biology of the grass. This practice can result in mismanagement of pastures, grazing too early in the season and over-stocking. As a result, the quality of the remaining prairies has been degraded, impacting associated wildlife species and reducing the economic returns to the landowner.

The goal of the Mixed-grass Prairie Grazing Management Project is to help conserve the native mixed-grass prairie ecosystem by promoting agricultural activities that incorporate wise land stewardship. This goal will be achieved by developing demonstration projects in the mixed-grass prairie area of agro-Manitoba as part of a multi-agency partnership. The objectives of this project are to maintain and enhance existing native grasslands and their associated wildlife species through promotion of effective management practices for native grasslands, establishing monitoring programs to determine vegetative, grassland bird and livestock responses to grazing, and assessing the economic returns of various grazing systems.

The main activities of this project include the establishment of grazing demonstration projects on private lands in southwestern Manitoba. Sites selected will be in areas where there are still large areas of native grassland and where cattle production is the primary land use. Monitoring will be a key aspect of the management regime as the grazing system will be based on adaptive management. Economic returns to the landowner will also be assessed. Comparisons will be made between the rotational system and the season-long grazing regime.

A many-faceted extension program will be developed for this project including: field days, tours, newsletters, presentations on the economic benefits, articles in a variety of publications, fact sheets, and seminars explaining the projects in each local community.

CONCLUSION

The loss of mixed-grass prairie in Manitoba over the past 200 years has been dramatic and the remaining prairie is being threatened by cultivation, inappropriate management, invasion of exotic species and encroachment by woody species. If mixed-grass prairie is to survive in Manitoba, initiatives such as the private land stewardship program and the grazing demonstration program must succeed. Cooperation and partnerships among government and non-government organizations and private landowners will be vital. The challenge for the future will be to ensure that this ecosystem is preserved in perpetuity.

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THE SUITABILITY OF RANGE CONDITION MEASURES FOR DETERMINING PLANT DIVERSITY WITHIN THE MIXED-GRASS ECOREGION OF SASKATCHEWAN

Laura C. Groskorth

#611, 429 - 14th Street NW, Calgary, Alberta, T2N 2A3

David A. Gauthier

Canadian Plains Research Centre, University of Regina, Regina, Saskatchewan S4S 0A2

Abstract: The preservation of biological diversity is considered important for a variety of reasons including economic value and preservation of natural ecosystem processes. Diversity data is expensive and time consuming to collect, and alternate methods of determining diversity could hasten the inventory of grasslands. The objectives of this study were to examine the relationships between measures of plant diversity and range condition in the mixed grassland of Saskatchewan, and to show how these relationships might allow range condition assessments to serve the dual purpose of range management and biodiversity inventory. Two data sets were compared in order to achieve these objectives: a range condition assessment data set and plant diversity assessment data set. There was a significant positive correlation between the number of species found through range condition methods and the number of species found through diversity assessment methods. Grouping of data into range condition classes (poor, fair, good, excellent), and comparing them to calculated Simpson's Biodiversity Index values revealed that the highest level of diversity occurred on ranges in good condition, or where livestock grazing levels were intermediate. Similarities in plant community groupings and plant community diversity as indicated by the two data sets were also found using multivariate statistics. The results indicated that data collected for the purpose of range condition assessment have potential for indicating plant diversity at a community level. Modifications to standard range condition assessment practices would facilitate this application. A better understanding of desirable grassland diversity levels is also required in order for this information to be applied effectively.

INTRODUCTION

Biological diversity (biodiversity) is the variety of living organisms, the genetic differences among them, the communities, ecosystems and landscapes in which they occur, plus the interactions of these components (West 1993). The preservation of biodiversity is considered important for many reasons including economic value and the preservation of essential ecosystem functions (Ehrlich and Wilson 1991, West 1993).

The southern portion of Saskatchewan is at high risk for loss of biodiversity (BSAT 1994). Almost all of the rough fescue grassland has been ploughed, only a fraction of the tall grass prairie still exists, and less than 25% of each of the once abundant short-grass prairie, mixed-grass prairie, and aspen parkland remain in its native state (Gauthier 1993).

The Saskatchewan Conservation Data Centre (SKCDC) conducted a project aimed at understanding and protecting biodiversity in Saskatchewan. They developed methods for sampling, describing, and predicting community plant biodiversity in the native grassland of prairie Saskatchewan (Wright et al. 1995). The SKCDC developed methods and sampled areas of the mixed-grass ecoregion in 1995 and 1996. As a joint project, the study reported here evaluated range condition at the same sites sampled for plant biodiversity by the SKCDC.

Range condition is a measure of the ability of the grassland to produce livestock, and is based on ecological principles. Because range condition is assessed based in part on the plant species composition of a given site, it was predicted to be a measure of plant species and community diversity on a coarse level. A study relating range condition to plant diversity had not yet been conducted in the mixed-grass ecoregion of

Saskatchewan, and previous grassland studies had not attempted to find a quantitative relationship between good range management practices and grassland biodiversity conservation.

The objectives of this study were: 1) To examine the relationship between measures of plant species/community diversity and range condition in the mixed-grass ecoregion of Saskatchewan, and 2) To show how these relationships might be used to better serve the dual purpose of range management and conservation.

STUDY AREA

This study area was selected within the mixed-grass ecoregion boundaries of Saskatchewan (Padbury and Acton 1994). The vegetation of the region is dominated by midgrasses such as needlegrass or speargrass (e.g. *Stipa comata*) and wheatgrasses (e.g. *Elymus lanceolatus*), and shortgrasses such as blue grama grass (*Bouteloua gracilis*) (Coupland 1961, Padbury and Acton 1994). Assemblages of plant species differ depending on soil texture, drainage, microclimate, and other physical characteristics of the landscape.

Nested within the mixed grassland ecoregions are soil landscape units (SLUs) for which there are specific attribute characteristics including soil development, soil texture, surface form, and topography (Gauthier 1993). It was from these soil landscape units that the study areas for this investigation were selected (Figure 1).

Contiguous landscapes with strong differences in local landform, soil parent material, and soil texture (enduring feature variables) were selected for sampling based on the idea that such landscapes were likely to show clear differences in plant community composition and diversity. Selection of the study areas and the study sites was governed by the requirements of the Prairie Biodiversity Study (PBS) of the SKCDC.

The soil landscape units involved were termed MKLM (morainal, knoll and kettle, loam), FHSL (glaciofluvial, hummocky, sandy loam), and MKCL (morainal, knoll and kettle, clay loam). "N" or "S" was used after the acronym to indicate sites in the north or south geographic study region (Wright et al. 1995).

Each study area contained some combination of the following soil associations; Amulet Orthic Dark Brown

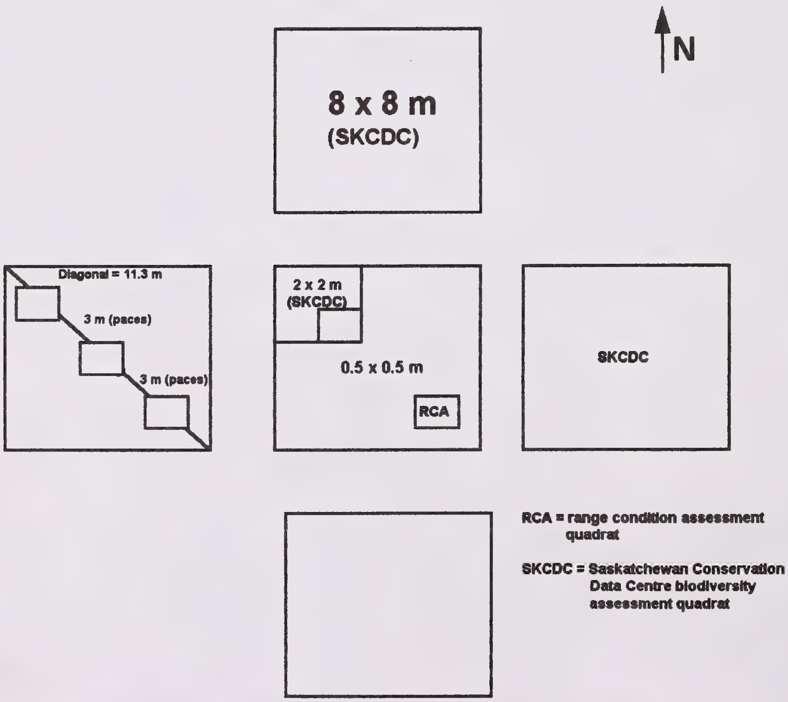

Figure 1. Orientation and Position of SKCDC and RCA sampling quadrats at one site.

(Am), Chaplin Orthic Brown (Ch), Fox Valley Orthic Brown (Fx), Hatton Orthic Brown (Ht), Haverhill Orthic Brown (Hr), and Hillwash (Hw). There was also soil texture information for each site. All soils information was verified using soils maps published by the Saskatchewan Institute of Pedology (Aynes et al. 1985) and field testing.

METHODOLOGY

Range condition assessments (RCAs) were conducted at as many of the PBS sites as possible, so that there would be a direct comparison between plant diversity data and range condition assessment data. In order to compare the data from the two collection methods, the RCA methods were modified.

SKCDC Prairie Biodiversity Survey Methods

Sample points from which actual field sites were located were randomly identified within each soil association along access roads, trails, or fire guards using Central Surveys and Mapping Agency photo maps (Wright et al. 1995). Sample sites had up to five 8 x 8 m quadrats available for sampling on the plateau and four cardinal direction aspects of the site depending on whether or not various criteria were met (Figure 1). The degree to which a particular soil type was sampled depended on how prevalent it was within the study area. For example if the Hr soil association contributed half of the total area of the study area, then half of the sites would be located in the Hr soil association (Wright et al. 1995). This resulted in most of the RCA study sites being of "loamy" range site type. Because this is one of the most common range site types in the mixed-grass ecoregion of Saskatchewan, it is thought that the data set is a typical representation of the grazed lands of the mixed-grass ecoregion of Saskatchewan (Abouguendia 1990).

SKCDC Quadrat Layout

Eight x eight m quadrats were oriented in a north-south and east-west direction with a 2 x 2 m quadrat nested in the northwest corner. Plateau quadrats were centred on the highest point of the hill and aspect quadrats were centred at the midpoint of slopes facing each of the four cardinal directions.

Following layout, quadrats were intensively examined and all species found were listed. All species present were assigned an estimate of areal cover using the Braun-Blanquet cover scale. Further details regarding the SKCDC's methods can be found in Wright et al. (1995).

Range Condition Assessment Methods

Range condition assessment (RCA) methods were determined using the Range Plan Development Guide (Abouguendia 1990) and through consultation with range ecologists. A 0.5 x 0.5 m quadrat was placed in the northwest corner, centre, and southeast corner of each 8 x 8 m SKCDC quadrat visited. One quadrat was placed at the mid slope position between the 8 x 8 m quadrats on each aspect. In this manner a minimum of ten and a maximum of nineteen 0.5 x 0.5 m quadrats were sampled (Figure 1).

Species within each 0.5 x 0.5 m quadrat were identified and recorded and unknown species were sampled for later identification. Plants were identified using various sources, including Looman (1982), Looman and Best (1979), Vance et al. (1991) and the expertise of the SKCDC field crew. The relative dry weight of live biomass for each species in the quadrat was estimated to the nearest 5% for a total weight of 100%. If a species contributed less than 5% it was recorded but not used in the final range assessment for the site.

From the soil zone (e.g. Brown), soil association (e.g. Hr), and soil texture (e.g. loamy), the range site type was determined. The range site types were then used to guide range evaluations using the vegetation composition charts in Appendix E of the Range Plan Development Guide (Abouguendia 1990) the primary method of range condition assessment in Saskatchewan.

RCA Calculation

The weighted score for each species was totaled at each site to give a percentage value. This value was used as the range condition score. A description was attached to each range of values; 0-25% = poor, 26-50% = fair, 51-75% = good, and 76-100% = excellent. If a range condition value was determined as good, it was interpreted that between 51 and 75% of the expected climax vegetation for that site type was present.

When range condition assessments are applied to stocking rates, scores may be adjusted according to plant vigour, litter cover, bare ground or ground cover of non-vascular species, slope, or all of the above. These factors are seen as indicators of changes in plant composition, degree of use, and erosion. These are subjective estimates important in effective livestock management. Because estimation of these factors further increased the subjectivity of sampling these adjustments were omitted from the scores used in the statistical analysis.

In total, 53 of the SKCDC sites were used in the final RCA analysis. The site locations varied between Prairie Farm Rehabilitation Administration (PFRA) pastures, provincially owned community pastures, and private lands. Range site types fell under the categories of thin, sands, sandy, and loamy. Seventy-four percent of the sites were loamy, with the remaining 26% of sites distributed between the other range site types.

The RCA data set and the SKCDC data set were compared. Each data set contained "quadrat" files or "site" files. The quadrat files contained information about each SKCDC quadrat sampled in the plant diversity survey and corresponding range condition information for the same area (equivalent to 3 RCA quadrats), whereas the site files contained information about a given site, involving from 2 to 5 SKCDC quadrats and from 10 to 19 RCA quadrats.

The analysis was divided into three main parts, and all tests were repeated separately for 1995, 1996, and combined 1995/1996 data. Firstly, species richness was examined to determine if there was a relationship between the number of species collected through the SKCDC and the RCA methods. The Spearman Rank Order Correlation (R) test was used and the resulting R value was rejected at the 95% confidence level for each of the three test combinations involving species richness (Case 1, 2 and 3) listed below. The combinations of quadrats or sites tested can be seen in Table 1.

Table 1. Correlation test results for number of SKCDC species compared to number of RCA species for one SKCDC quadrat (1995/1996 combined data).

quadrats Used	Valid N	Spearman R	p-level
all	67	0.67	0.000
North	45	0.55	0.000
South	22	0.67	0.001
North; mklm	24	0.46	0.025
North; fhsl	21	0.6	0.004
South; mkcl	20	0.64	0.002
South; fhsl	2	n/a	n/a*
North; Fx	5	0.8	ns~
North; Hr	35	0.64	0.000
North; Ht	1	n/a	n/a
North; Ch	2	n/a	n/a
North; Hw	2	n/a	n/a
South; Am	20	0.64	0.002
South; Ht	2	n/a	n/a
North; loamy	33	0.48	0.005
North; sandy	10	0.78	0.007
North; sands	0	n/a	n/a
North; thin	2	n/a	n/a
South; loamy	20	0.64	0.002
South; sandy	0	n/a	n/a
South; sands	2	n/a	n/a
All; loamy	53	0.65	0.000
All; sandy	10	0.78	0.007
All; sands	2	n/a	n/a
All; thin	2	n/a	n/a
All; east aspects	9	0.71	0.033
All; west aspects	13	0.55	ns
All; north aspects	6	0.64	ns
All; south aspects	13	0.51	ns
All; plateau quadrats	26	0.66	0.000

n/a = N too small to perform test
ns = not significant

Case 1: Number of species in an SKCDC quadrat was compared to number of species found using RCA methods within the same area (one 8 x 8 m SKCDC quadrat = three 0.5 x 0.5 m RCA quadrats). Case 2: Mean number of species found in all the quadrats sampled at an SKCDC site was compared to the RCA value (%) for the entire site. Case 3: Number of species found in each SKCDC quadrat was compared to the RCA value (%) calculated for the entire site in which the SKCDC quadrat in question was located.

The second part of the analysis involved calculation of the Simpson's Biodiversity Index (D) for each SKCDC quadrat. The formula used was:

$$D = \sum (n_i(n_i-1)/N(N-1))$$

where n_i = the cover value of the $_i$th species, and N = the total cover value. As D increases, diversity decreases, therefore the inverse Simpson's Index is normally used (1/D). The 1/D was compared between groupings of range condition values by SKCDC quadrat. This meant that the calculated diversity for one SKCDC quadrat was compared to the range condition value for the site in which the quadrat was found. Range condition values were first grouped by the traditional management approach (poor = 0-25%, fair = 26-50%, good = 51-75%, excellent = 76-100%), and then regrouped into categories of 10% (0-10, 11-20, etc.). The Kruskal-Wallis analysis of variance by ranks was used to compare diversity indices to range condition class by both groupings. Line diagrams were also prepared for the quadrat files to show trends in diversity index values relative to the range condition value.

Multivariate statistics were used in the third portion of the analysis. SYNTAX software was used to perform plant community ordination and classification procedures on both the SKCDC data and the RCA data. While the procedures were intended primarily to characterize plant communities within soil landscape units for the SKCDC, the same tests were run on RCA data to determine if range condition assessment methods would produce comparable results and have any predictive value regarding plant community diversity.

The Principal Coordinates ordination technique was used. For each axis in the Principal coordinates analysis, an eigenvalue was calculated, which is a representation of the variance accounted for by that axis. The axes are then ranked by their eigenvalues. If the cloud of points is concentrated in certain directions, most of the original total variance will be extracted in the early eigenvalues, and later eigenvalues will be small or zero (Gauch 1982). In a typical community study, the first three eigenvalues account for 40 - 90% of the total variance.

A hierarchical, polythetic agglomerative classification procedure was used. Groups classified were arranged in a hierarchy and grouped in increasingly large clusters based on their calculated dissimilarity. The result was a dendrogram with study sites listed down a left hand column with groupings decreasing toward one large group in the right hand column.

RESULTS

Case 1: In almost every case where the sample size was large enough, the correlation tests revealed a significant positive correlation ($p \leq 0.05$) between the number of species found using the RCA method and number of species found using the SKCDC method. This suggests that if range condition assessments were performed in two separate areas, one could predict which landscape would have the higher overall species richness. Table 1 contains an example of these results for the combined years data.

Case 2: None of the correlation tests revealed a significant result between number of SKCDC species and the RCA value(%), except for loamy range site types in the southern study area, where the average number of SKCDC species at a site was positively correlated to the range condition value ($R=0.53$, $p=0.023$).

Case 3: A significant yet weak negative correlation was found for "all" quadrats in 1995,1996, and the 1995/1996 combined data set for this case. This would suggest that with higher range condition, fewer species are found. Divisions of the other environmental factors did not show significant relationships, except for northern sandy range site types in 1995 ($R= -0.81$, $p=0.004$), and in 1996 Ht soil associations in the south ($R= -0.68$, $p=0.010$), eastern aspects ($R= -0.54$, $p=0.010$), northern aspects ($R= -0.63$, $p=0.050$), and plateau quadrats ($R= -0.38$, $p=0.034$). Similar results were found for the combined 1995/1996 data set, with the addition of significant negative correlations between number of species for a quadrat and the range condition for a site for North, MKLM sites ($R= -0.31$, $p=0.031$), All, loamy sites ($R= -0.18$, $p=0.049$), and All eastern aspects ($R= -0.49$, $p=0.006$). South, Am sites also showed a significant positive correlation between number of species for a quadrat and the range condition for a site ($R=0.39$, $p=0.003$).

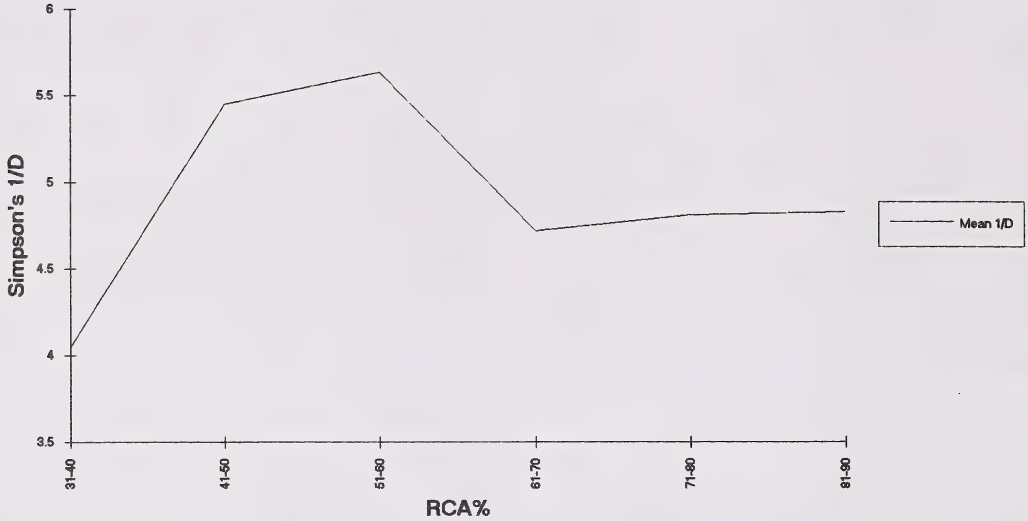

Figure 2. Line diagram depicting the mean inverse Simpson's Biodiversity Index for combined 1995/1996 range condition values.

No significant differences were found for the Simpson's Index between groups of range condition values, however, line diagrams plotting the data showed a repetitive trend. The Simpson's Index of Diversity peaked at the 51-60% range condition in 1995, 1996, and the combined 1995/1996 data sets. Diversity then dropped off consistently toward the higher and lower range condition classes (Figure 2).

Multivariate Statistics

Each soil landscape unit (SLU) in the northern and the southern study areas can be represented by a pie diagram showing the relative proportion that the community types contribute to each SLU (given the number of samples vary for each SLU). This indicated the community diversity of each SLU. Examples of these pie diagrams are shown in Figure 3.

Because ground covering species such as club moss (*Selaginella densa*) and moss phlox (*Phlox hoodii*) were included in the SKCDC samples but were considered separately for the purpose of range condition assessment, the dominant species compositions for both sampling procedures were also different. The RCA sampling also represented fewer sites sampled than the SKCDC sampling.

In the 1995/1996 data set eight species (*Rosa woodsii, Stipa comata, Stipa curtiseta, Koeleria macrantha, Elymus lanceolatus, Carex spp., Bouteloua gracilis*, and *Artemesia frigida*) of the fifteen dominant species identified in the SKCDC classification were also used for the RCA classification, in addition to five unique species in the RCA classification (*Thermopsis rhombifolia, Agropyron cristatum, Gutterizia sarothrae, Festuca hallii*, and *Agropyron smithii*). Of the seven SKCDC species not used (*Symphorocarpus occidentalis, Selaginella densa, Rosa arkansana, Phlox hoodii, Lichen spp., Helictotrichon hookeri* and *Nassela viridula*), three were of the ground cover type mentioned earlier.

Proportions of contributions made by each vegetation community type were similar but not identical for RCA and SKCDC data. For example, in the case of MKLM north, SKCDC's classification showed the SLU being composed of five community types in similar proportion, not unlike the representation for RCA data (Figure 3). SKCDC's MKLM south also shows five community types, but is dominated by two of the types as with the RCA pie graph representation. FHSL north is perhaps the most different between the two data sets, as in SKCDC's case it is represented by similar proportions of seven different community types while the proportions in the RCA data are more unequal. The pie graph for FHSL south is very similar between the RCA and SKCDC classifications. Both are represented by three communities, with one community type representing at least 60% of the SLU.

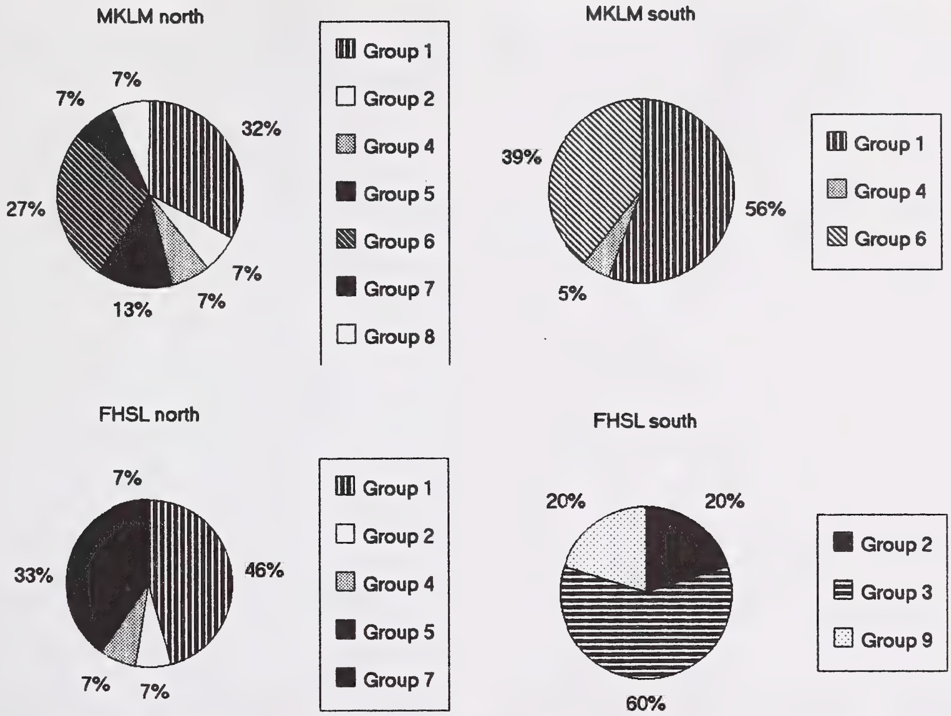

Figure 3. Pie diagrams depicting the diversity of each soil landscape unit in terms of vegetation community types (based on classification of the 1995/1996 RCA data).

DISCUSSION

Examination of the relationship between plant species/community diversity and range condition in the mixed-grass ecoregion of Saskatchewan demonstrates that the information collected for the purpose of range management is also useful for the assessment of grassland plant diversity.

The goal of range management, cattle production, requires a healthy range. Conservation ecologists are not interested in production specifically, but in the species composition and the integrity of the grassland ecosystem. The principal indicator of range condition is species composition. Because of this, it was hypothesized at the beginning of this study that information collected in order to assess range condition could provide valuable information for ecologists studying the plant diversity of the grassland system from a conservation perspective.

The area surveyed for a range assessment is usually much smaller than the area surveyed for a biodiversity assessment and consequently reveals fewer species. This phenomenon can be explained by the species-area curve (Colinvaux 1985, Wright et al. 1995). Neither a range condition assessment nor a biodiversity assessment is likely to sample every species in a given plant community, but both give some indication of the species present.

Conducting field work to fulfill a biodiversity inventory is incredibly time consuming and labour intensive. This is partly because methods are experimental, skilled staff and resources are scarce, the work is time consuming and difficult, access to study sites is limited and an inventory requires a level of detail which limits the amount of data that can be collected in the length of one field season. With reduced program budgets and increasing urgency to understand and sustainably utilize our resources, it would be fitting to use information that is routinely collected in an expedient manner by skilled professionals to fulfill conservation data base needs. Range evaluations are quick, and are routinely performed on certain pastures to ensure the wise and sustainable use of the grassland. Efforts are constantly being made to better manage the grassland for livestock production, to encourage ranchers to monitor their own ranges and to improve the range assessment methods (Abouguendia 1996, Adams and Fitch 1995, Bradley and Wallis 1996, National Research Council 1994, Pepper 1994).

Given the significant positive correlations in the results, the relative species richness of two areas could be compared satisfactorily using range condition assessment data which already exists, or which would be collected for the purpose of range management. If one site is assessed as having a greater number of species than another using range assessment data, then we would expect to find the same result from a plant diversity assessment. This finding has implications for native grassland conservation in general and for the preservation of rare species.

The final correlation test indicated that as range condition increased, an overall decrease in the species richness found through biodiversity survey methods occurred. With the correlation values being low and occasionally positive, (e.g. "South, loamy" sites) it is evident that the relationship is not linear. Disturbance is thought to be a mechanism which controls the ability of competitively dominant species to take over the community (competing for such resources as light, water, and nutrients); therefore disturbance can affect plant diversity. Less competitive species may have superior tolerance to disturbance forms such as grazing, allowing them to persist where moderate disturbance is present. While the plant community structures of the sites tested in this study suggest complexity in their relationship with range condition, it appears that an overall decrease in species richness with increasing range condition prevails. The gradient of increasing range condition could also be viewed as a gradient of decreasing environmental disturbance.

Observations in the field suggest that an inverse relationship between species richness and range condition is possible. Range ecologists predict that the highest species richness is likely to occur at the "good" range condition, but in "excellent" range condition the competitively dominant species will crowd out less competitive species (Nykoluk 1995, Willoughby 1992). Smith et al. (1996) found that plant species diversity was greater on the good compared to the excellent condition range, as was found in this study. Smith et al.'s (1996) study was conducted in desert conditions rather than the mixed-grass prairie.

Biodiversity Index

Species richness by itself gives no indication of the abundance of species relative to one another, and may depict sites being similar to one another when in fact their species assemblage is quite different (Magurran 1988). While no significant differences were found using the analysis of variance on biodiversity indices grouped by range class, it is possible that with the addition of a measure of evenness, the differences in diversity between sites of different range condition were minimal. It is also possible that the changes in diversity across the range condition gradient are real, but subtle, and the degree to which the diversity changes depends upon the various physical factors creating the plant community (soil texture, slope, aspect etc.). The assemblage of species in a plant community may change gradually along an environmental gradient, making it very difficult to determine distinct differences between certain points along the environmental axis.

The simple line diagram that visually described the relationship between range condition and biodiversity (Figure 2) follows predicted trends. The mean biodiversity index is consistently at its peak in the 51-60% range condition class for all data. This is a striking reflection of Grime's (1979) intermediate disturbance hypothesis. The result is the predicted scenario for grasslands (Milchunas et al. 1988, Nykoluk 1995, and Willoughby 1992).

From this study we can say that in the mixed-grass ecoregion of Saskatchewan, we will find the highest plant diversity in areas with a good range condition class, particularly on loamy sites. This occurs whether richness is examined alone or when it is combined with evenness to produce a single index. High diversity is not necessarily the most desirable case. The diversity of an area should reflect the expected assemblage of plant species under a natural disturbance regime. Based on our knowledge of the condition of a range through previous management efforts, we can predict the level of diversity we are likely to find in a given area.

If we consider the results in terms of the evolutionary history of the mixed-grass prairie under considerable grazing pressure from large generalist herbivores (e.g. Bison (*Bison bison*)), then we might assume that high diversity (or a "good" range condition rating) is the most desirable. A range in stable, good condition is an indication to range managers that the range is producing well economically and is not being damaged irreversibly. An environmental ecologist might favour the "good" condition because of its genetic potential and because it approximates the historical grassland grazing regime. The difference is that range managers ultimately strive for "excellent" condition and are concerned about the species assemblage as it applies to cattle production.

Multivariate Statistics

Multivariate statistics served to summarize plant community data. The ordination procedure revealed that the data values were sufficiently clustered to warrant the use of a classification procedure. In considering results of the classification procedure, it is important to remember that the SKCDC used a Braun Blanquet scale of abundance in the biodiversity inventory, while the range condition portion of the study required the use of a percentage live biomass (or edible biomass) abundance scale. The RCA data set and the SKCDC data set also differed in sampling procedures and the treatment of ground covering species such as moss phlox (*Phlox hoodii*) and little club moss (*Selaginella densa*). In range condition assessments, these species are seen as indicators of range condition separate from the differential weighting of palatable species for grazing. Ground cover species are typically not grazed by livestock, but are seen as an indicator of moisture (club moss retains a lot of moisture), and of fire (ground cover species are more prolific in areas where fire has been suppressed). In contrast, ground cover species are treated equally to other species in a community ecology study. As a result, the ground cover species are measured differently in the two types of study.

Ground cover species were ignored when choosing the five dominants from the RCA classification results in order to elucidate finer similarities and differences between RCA and SKCDC data. It is important to remember the contribution of the ground cover species to the plant community organization when interpreting and comparing results.

The dominant species selected for the SKCDC and the RCA classification procedures were also similar, and in many cases the differences could be explained by the previously mentioned sampling or cover species measure differences. The overall interpretation of the classification results is that the two data sets, the RCA and the SKCDC, revealed strikingly similar results despite great differences in methods. This is evidence that grassland community studies could take advantage of existing range condition data to reveal important aspects of community structure and diversity. It would appear that RCA data is capable of revealing ecologically dominant species and overall species composition. This is a logical finding since RCAs are ecologically based and rely heavily on soils information. When ground cover species are taken into consideration, a range condition data set may be just as useful for revealing community structure as a data set designed specifically for that purpose. Range condition assessment data could certainly direct sampling efforts. Cross referenced with soils information, one could determine plant community information before spending additional funds on field work. One could also perform a range assessment (or a modified assessment as in this study) for a quick reference of plant community information.

The information about the plant diversity of grasslands afforded by range condition evaluations can be summarized as being more general than that of an in depth community ecology/plant biodiversity study. It can provide useful and accurate information about the community diversity of a landscape, the types of communities contained within a landscape and the relative species richness and overall biodiversity (evenness included) of different communities. Diversity can also be predicted based on the level of grazing disturbance in an area. Based on our knowledge of the methodological differences between productivity oriented range condition assessments and research oriented plant ecology studies, we could interpret the vast quantities of range data accordingly. Using this data to its full advantage would increase the inventory of grasslands tremendously from the conservation ecologists perspective, improve and strengthen communication and working relationships between range personnel and researchers and increase our chances of using the grassland in a sustainable manner.

Given our knowledge that range condition assessments contribute valuable ecological and plant diversity information, ideally range managers and grassland researchers could coordinate field research and the maintenance of a biodiversity data base. Such efforts would add to the knowledge of grassland plant communities, the relationship between grazing and biodiversity, and in turn direct efforts for the successful improvement of range condition assessment methods.

ACKNOWLEDGMENTS

Funding was provided for this project by the Canada-Saskatchewan Agriculture Green Plan Agreement. The project would not have been possible without the cooperation of the Saskatchewan Conservation Data Centre, the Prairie Farm Rehabilitation Administration, and several land owners and pasture managers. Technical assistance was provided by Chris Nykoluk and Tom Harrison.

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WETLANDS

STABLE CARBON, NITROGEN, AND SULFUR ISOTOPE DETERMINATIONS OF TROPHIC RELATIONSHIPS IN PRAIRIE POTHOLE WETLANDS

Dale Wrubleski

Ducks Unlimited Canada, Stonewall P.O. Box 1160, Oak Hammock Marsh, Manitoba R0C 2Z0

Naomi E. Detenbeck

U.S. Environmental Protection Agency, Duluth, Minnesota

Abstract: We used the stable isotopes of carbon, nitrogen, and sulfur to examine the food webs of 10 prairie pothole wetlands in south-central North Dakota in 1994 and 1995. Stable carbon isotope ratios were useful for separating algal and vascular plant sources of organic matter. Algae were more deplete than the emergent macrophytes growing within the wetlands and the terrestrial vegetation growing around the wetlands. Most aquatic invertebrates showed deplete carbon signatures consistent with consumption of algae. Only the snails showed enriched carbon signatures indicating consumption of macrophyte detritus. Young waterfowl showed a shift in carbon signatures consistent with changes in diet with growth development. Nitrogen and sulfur isotope ratios showed considerable overlap among all primary producers and were not useful for identifying trophic structure within these wetlands. Sulfur isotope ratios were similar among all primary producers within individual wetlands, but showed consistent differences among wetlands. These differences are believed to be due to wetland elevation and groundwater inputs. Nitrogen isotope ratios also varied among wetlands, but only for the emergent macrophytes, indicating differences in nitrogen sources within individual wetlands.

DISTRIBUTION OF AGRICULTURAL PESTICIDES IN PRAIRIE WETLANDS

Gordon Goldsborough
University of Manitoba, Winnipeg, Manitoba

Abstract: There is abundant, albeit fragmentary, evidence that prairie wetlands are being contaminated extensively by agricultural pesticides (primarily herbicides and insecticides) and other anthropogenic contaminants. Such inputs can affect fundamental ecosystem properties, such as primary production, which in turn affect habitat and resource supply for wetland fauna. I review data on the use of pesticides, the off-site transport of residues from treated land, and the frequency with which these residues are subsequently detected in receiving streams and wetlands on the prairies. As the environmental distribution of a pesticide is affected by its chemical and physical properties, and the abiotic and biotic properties of the receiving wetland, insight into its ecological impacts will derive from consideration of the underlying partitioning and degradative processes that determine distribution rather than case-by-case studies of persistence. Future research on chemical contamination of prairie wetlands should include the development and testing of dissipation and fate models under conditions typical of prairie wetlands using a process-oriented approach, with emphasis on the roles of absorption and photolysis in a shallow, high area-to-volume environment. Output from a computer model based on the fugacity concept (QWASFI) shows how it may be possible to predict the environmental behavior of specific chemicals in wetlands.

BOTULISM IN PRAIRIE WETLANDS

G. Wobeser

Canadian Cooperative Wildlife Health Centre, Department of Veterinary Pathology, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan

Abstract: Avian botulism is a food poisoning that occurs when wild birds ingest preformed toxin produced by the bacterium *Clostridium botulinum* type C. Major die-offs of waterfowl have been reported on some prairie wetlands from the first decade of this century, and the disease occurs somewhere in the prairie provinces each year. Spores produced by the bacterium are extremely resistant and persist in wetland soil for years, even when the wetland is completely dry. Under suitable conditions, which include a protein-rich substrate, anaerobic conditions, and warm temperatures, the spores germinate, grow and produce toxin. The decaying carcass of a vertebrate provides ideal substrate for toxin production; birds become poisoned by ingesting toxin-laden maggots and other invertebrates that feed on such carcasses. The carcasses of birds that die of botulism provide further substrate for toxin production, so that the extent of mortality on a marsh can escalate rapidly. Waterfowl concentrated on large wetlands during the mid-summer moult are particularly at risk; estimated losses in some years may exceed one million ducks. Losses of other species, such as shorebirds, may be extensive but are not well characterized. The disease can not be prevented at present. A cooperative regional investigation program is underway in the three prairie provinces to assess the impact of botulism on bird populations and to develop adaptive management techniques to reduce losses.

Avian botulism is a neuroparalytic condition that probably kills more wild birds than any other disease. The disease occurs worldwide but is most frequent in western North America, where major outbreaks occur each year. The condition appears to be a natural component of the ecology of prairie wetlands and there is a long history of outbreaks in western Canada. Although many of the early reports are anecdotal, there is little doubt that large die-offs reported in the early years of this century were the result of botulism. Botulism occurs on some wetlands on the prairies every year, although the number of birds that die in any year is highly variable.

Botulism is a form of food poisoning, in which birds become poisoned by ingesting material containing preformed toxin produced by the bacterium *Clostridium botulinum* type C. This bacterium grows in decaying organic material and is probably one component of the normal decomposition process of organic material in wetlands. If an outbreak of botulism is to occur on a wetland, certain basic features must be present and the probability of an outbreak occurring is further modified by a large number of poorly defined variables. The basic features include the presence of :

- a toxigenic strain of *Clostridium botulinum* type C
- suitable substrate within which the bacterium can grow and produce toxin
- suitable environmental conditions for bacterial growth (anaerobic, warm temperature)
- a method for transferring the toxin from the substrate to birds
- a population of susceptible birds

Clostridium botulinum type C is very common in the soil of wetlands. There are large differences in the density of the organism among wetlands but it is likely that all wetlands contain the organism. The bacterium is usually present in the form of spores that are extremely resistant and persist for many years, even when the wetland is dry. Spores are ingested constantly by animals that live in wetlands. The spores appear not to germinate in the digestive tract of living animals and do not cause the animals any harm. However, the spores will germinate and grow in protein-rich substrates that are anaerobic, so that if an animal dies with spores within its intestine, the spores may germinate and grow in its carcass. Carcasses appear to be the ideal substrate for bacterial growth and toxin production, because in addition to being anaerobic and providing a protein-rich milieu, decomposing carcasses develop the high temperatures (35ºC) that are optimal for the bacterium. Animals of all types, both vertebrate and invertebrate, die continuously in wetlands, so that carcass material is widely available in wetlands to serve as a substrate for the bacterium. Natural events such as hail storms or blue-green algae blooms that kill large numbers of animals are suspected to have been the initiating event in some botulism outbreaks. Birds that died as a result of colliding with overhead wires have also been linked to botulism. Although the bacterium may grow and produce toxin in other substrates, this has not been demonstrated to be important in natural outbreaks.

Most birds do not feed directly on carcasses but will feed on invertebrates that have ingested carcass material containing toxin. Invertebrates such as fly maggots are not affected by the toxin but as few as 1 to 10 maggots may contain sufficient toxin to poison a duck. During a botulism outbreak, each bird that dies becomes potential substrate for the production of more toxin. Hundreds or thousands of maggots may be produced in a single vertebrate carcass, so that there is a great potential for the disease to expand rapidly. (Botulism is unique among intoxications in that each victim may be a source of toxin that leads to the death of other victims.)

A question that must be addressed is why this disease should be a cause for concern, if it is a natural phenomenon and part of the ecology of prairie wetlands. The disease concerns waterfowl managers because of the extent of the losses that occur in some years (Table 1). Most of the information on bird deaths refer to the number of carcasses that were collected; these represent an unknown proportion of the birds that actually died. It appears that in some years the mortality on a single lake used by many moulting waterfowl may equal or exceed the number of birds produced on very large areas of the prairies. Thus, botulism may negate the positive effects of major habitat restoration projects, such as portions of the North American Waterfowl Management Plan. (The impact of habitat loss and the resulting restriction of the area used by moulting birds on botulism are unknown.)

There is special concern for some avian species. The northern pintail has not responded as well as most prairie-nesting ducks to favourable water conditions in the 1990's and its population remains low. The major botulism-prone marshes on the Canadian prairies are located in the heart of the breeding ground for this species, and pintails comprise about 20% of the total mortality in some outbreaks. There is also concern about the impact of botulism on some non-waterfowl species, particularly shorebirds. The methods used in the past to assess bird mortality do not provide an adequate measure of shorebird losses, so the impact of botulism on these birds is unknown. This is particularly troubling because most of the lakes on which botulism occurs are important for shorebirds.

Botulism is of public concern to some groups and these create pressure for something to be done. Current management is centred on collection and disposal of carcasses. While this seems intuitively to be an appropriate method to reduce losses, there is inadequate information available to assess the actual effectiveness of the technique. Carcass collection is expensive and time-consuming; the average cost in recent years on the prairies has been several dollars per carcass collected. This cost must be balanced against the use of the same funds and effort for other conservation purposes; and managers must consider the opportunities that are being foregone as a result of botulism.

There is a general conclusion that botulism can not be prevented and that it is a feature of prairie wetlands; if management is necessary it will be directed at reducing the extent of losses. During the past two years, the investigation and management of botulism on the Canadian prairies has undergone a major change. This has involved a shift in focus from attempting to deal with the disease on an individual wetland basis in each province, to one in which the disease is being addressed on a cooperative regional basis across the prairies. Common methods for collecting data have and are being developed and a system has evolved for the exchange of information on both the ecological factors associated with outbreaks and on management techniques. The aim of this program is to improve understanding of the factors that result in large outbreaks and of the population impact of the disease, so that a system of adaptive management can be developed. The cooperating agencies in this program are Environment Canada, Ducks Unlimited Canada, the resources agencies of the three provinces, the California Waterfowl Association, and the Canadian Cooperative Wildlife Health Centre.

Table 1. Number of bird carcasses collected in recent major botulism outbreaks in the southern Canadian prairies.

	1994	1995	1996	1997
Pakowki Lake (Alberta)	31000	100000	12000	45000
Whitewater Lake (Manitoba)	??	3400	117000	49000
Old Wives Lake (Sask)	16,000*	??	136,000*	500,000**

* minimal estimate of mortality

** estimate based on regular sampling of transect lines

EVALUATION OF RESTORED WETLANDS IN THE PRAIRIE POTHOLE REGION OF THE UNITED STATES: A MULTIDISCIPLINARY AND MULTIAGENCY APPROACH

Ned H. Euliss, Jr. and Robert A Gleason

Northern Prairie Science Centre, US Geological Survey, 8711 37th Street SE, Jamestown, North Dakota 58401-7317

Abstract: The prairie pothole region (PPR) is a major producer of cereal grains and is the most important area in the United States for the Production of dabbling ducks. The value of the PPR for agriculture has led to the loss of over half of the original 8 million ha of wetlands. Concern over wetland loss coupled with an increased knowledge of the functions and values of wetlands has resulted in considerable wetland restoration activity in the PPR. Based on the total number of wetland basins, more wetlands have been restored in the PPR (estimates exceed 40,000 basins) than in any other region in the United States. While considerable effort has been expended to restore previously drained wetlands, there has been no parallel effort to evaluate restored wetlands relative to the goals of various natural resource organizations or to the ecological functions of their natural wetland analogues. Our presentation described an ongoing effort to evaluate restored wetlands in the United States PPR relative to various wetland analogues and to the diverse goals of multiple organizations and agencies.

CLIMATE AND WETLANDS: PAST LESSONS AND FUTURE POSSIBILITIES

Elaine Wheaton

Saskatchewan Research Council, 15 Innovation Boulevard, Saskatoon, Saskatchewan S7N 2X8

Abstract: Wetlands are a valuable part of the environment, society and economy, besides being important in their own right. Their numerous roles include habitat, water supply and quality, aesthetics, recreation, and climatic controls. Prairie wetlands are very sensitive to climate because the sloughs are shallow and because the climate is highly variable and semiarid. Past changes in Canadian prairie climates, wetlands and their relationships are examined. Indirect linkages of climate with wetlands, through adaptive responses of agriculture and other human activities to climate, are also important. Lessons from the past, such as the droughts of the 1980s and floods of more recent years, could be harbingers of the future. Future climates are expected to bring more intense and frequent droughts and wet spells. What might this mean for prairie wetlands? The convergence of human activities and climatic change could accelerate the disappearance, various changes, and the degradation of wetlands. What research, technology transfer and other activities are required.

ADAPTIVE MANAGEMENT

WILL WE EVER SEE THE FORESTS FOR THE TREES? THE NEED FOR ADAPTIVE FOREST ECOSYSTEM BASED MANAGEMENT IN SASKATCHEWAN'S FORESTS

Allan Willcocks

Forest Ecosystems Branch, Saskatchewan Environment and Resource Management, Prince Albert, SK

Abstract: Ecological management includes human and natural processes. These processes are little understood, yet the benefits are required now in spite of the lack of knowledge. Adaptive management provides the mechanism to learn about ecological processes, essential for long term ecosystem health and sustainability. It also provides the vehicle to apply management options that ensure present benefits from the forest, with long term sustainability in view.

Present management systems for components or single-use benefits of the ecosystem make it very difficult for effective adaptive management. In the Information Age, this situation of single-use management and policies makes neighbors disagree, splits communities and enables lawyers and lobbyists to prosper. Social and natural scientists increasingly find themselves engaged in emotional rather than scientific arguments concerning resource use. Society, which really drives resource management decisions, can't see the forest (total benefit of the forest) because of the trees (single or special use interest groups).

Saskatchewan Environment and Resource Management (SERM) has developed an adaptive ecosystem management model to manage its forests that links the natural ecosystem processes with societal needs. The key components include public input (knowledge exchange), natural science knowledge input, ecological monitoring and audit.

This adaptive system, if applied, will develop the knowledge and trust required to allow society to determine its needs from the forest, apply management options, and monitor and learn from its results.

The key to this system is modest investment by government and forest benefactors that will ensure long term sustainability and ecosystem health. Alternatively, inadequate investments will ensure a crisis in our forest ecosystems, which will result in much fewer benefits from the forest and collapse of portions of society dependent on these resources (e.g. forest communities). Also, inadequate application of this model will result in continual conflict between different sectors of society who will work to lobby for "their" part of the forest ecosystem.

INTRODUCTION

Aldo Leopold (1948) in "A Sand County Almanac" claimed that conservation was getting nowhere because it is incompatible with "our Abrahamic concept of land" in which we consider land as a commodity belonging to us. In other words, we control it through land management with the basic tool being "prescriptions" as the key medium for control. He went into his classical essay in which the ecosystem was described as interrelated and connected and very complicated.

Many interpreted that belief to mean that nature should not be manipulated and that man is best left out of the ecosystem: places should be set aside in perpetuity as untouched wilderness. However, Leopold believed that " when we see land as a community to which we belong, we may begin to use it with love and respect". He believed that man was very much part of the ecosystem, with all of his societal and economic baggage. In many ways, society misinterpreted early ecological writings of Leopold and others by seeing the components of a woodlot as static interrelationships. What they missed were the changing spatial, temporal and societal components of ecosystems that dominate

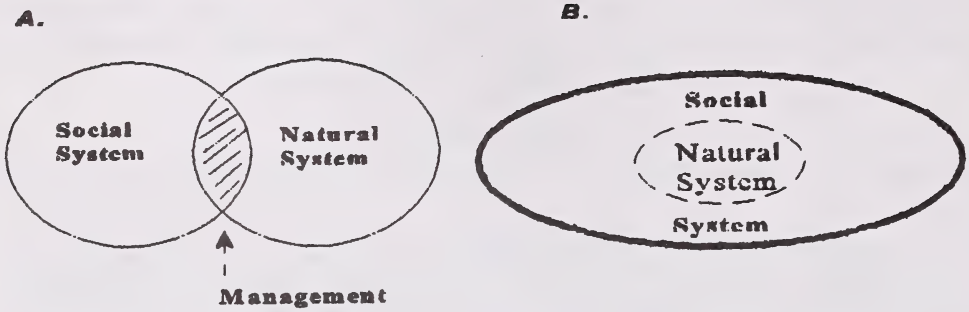

Figure 1. A is the typical diagram showing where the natural and social systems interface (Bormann et al. 1993) and B is our version of the "egg analogy". (from Vogt *et al.* 1996; used with permission of Springer-Verlag)

the outcomes of resource management. They couldn't see the big picture or forest because they were focused on the little things that made up the woodlot - the trees.

An ecosystem can be described as an interacting system comprising living organisms together with their non-living habitat. Humans are very much part of the ecosystem (Leopold 1948, Maser 1994). Vogt et al. (1996) described ecosystem management as primarily about human values. They felt that ecosystem management is the realization that the social system ultimately puts boundaries and constraints on our ability to manage the biological system (Figure 1). Consider the natural system as the yolk of an egg and the social system as the shell.

Alternatively, Haynes et al. (1996) considered socio-economic influences as the yolk, influencing the brittle egg shell which is the biophysical system. (Figure 2). Both analogies suggest that separating "people" from nature is impossible.

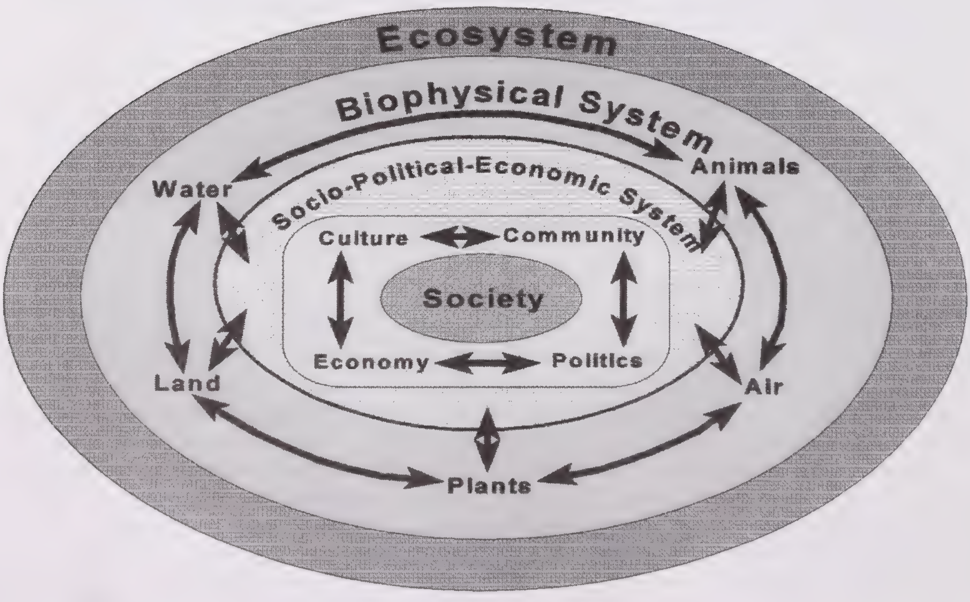

Figure 2. Socio-political-economic and biophysical systems in an ecosystem (from Haynes et al. 1996).

Contrast this to the perception in society that there are areas where natural systems are separated from social or human influences. Vogt et al. (1996) and Maser (1994) believed that natural systems cannot be separated from society. For example, even the most isolated areas north of the Churchill River may still be affected by global warming.

Maser (1994) defined the ecosystem approach as meaning that "... the 'system' in 'ecosystem' embodies three fundamental concepts: designating the physical boundary of the system and its components, understanding the interaction of its parts as a functioning whole; and understanding the relation between the system and its context." He believed that context means external factors that influence the system (e.g. global warming) as well as the internal ecological mechanisms of the ecosystems contained in the boundaries. He further defined ecosystem management as "... a system of making, implementing and evaluating decisions based on the ecosystem approach, which recognizes that ecosystems and society are inexorably linked and always changing".

Changing elements include natural factors such as disturbance, succession and natural selection along with changing societal values and knowledge. Most management is still largely based on individual parts of an ecosystem such as trees, water, wildlife, economic development, wilderness and grazing.

Much management is based on the premise that we can control the components of the ecosystem through prescriptions, in contrast to what Leopold (1948) recommended. It also assumes that we have a collective goal for each component. Our prescriptions in Saskatchewan to achieve individuals goals of ecosystem components include parks, timber management agreements, water agreements, grazing permits, silvicultural prescriptions and economic development plans, to name a few.

Maser (1994) believes that we cannot control the ecosystem by management, but can only

> "... [manipulate] some portion of the ecosystem in an attempt to cause it to behave in a particular way that we find satisfying to our societal values".

Most believe that there is not enough known about ecosystems to either control or manage them, yet society demands value now from our ecosystems.

Adaptive management (Figure 3) is the tool that allows society to benefit from the value of ecosystems such as our forests. It assumes that knowledge is limited but society requires value from our resource now.

It assumes that the management system is ever changing, based on new knowledge and new societal needs and values: a moving target. In Saskatchewan Environment and Resource Management, forest ecosystem management is defined in Figure 3 as an adaptive approach patterned after Willcocks et al. (1990) and Baskerville (1985). This management system has a built-in learning process, with the design of management goals, actions, and the measurement of progress, that allows the manager to learn about the system from his management of it. It assumes that the management system is an open-ended experiment in which a hypothesis is set, based on a future desired condition of the forest. This future desired condition is visualized based on societal values and needs, balanced with the need to ensure sustainable benefits from the forest. These benefits include such things as fibre for mills and wilderness experiences for people.

Once this future desired condition is determined, the potential sustainable benefits of the forest are allocated to timber companies, to trappers, to wilderness areas and other forest users. A key element in adaptive management is that there is a continual auditing process comparing the predicted end result of implementation

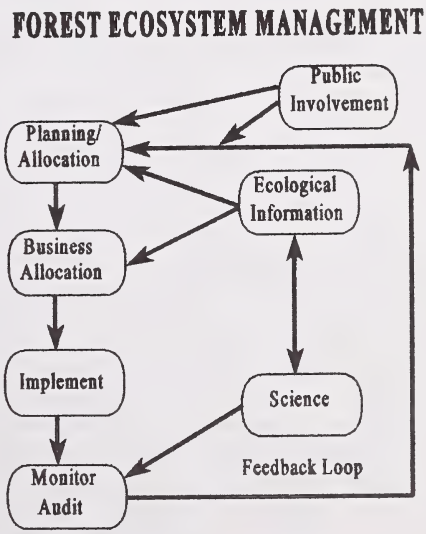

Figure 3. Forest ecosystem management.

(hypothesis) and the actual result. This provides the manager and society with a continual learning experience that is translated into improved practices. Even if the predicted end result is achieved, is the result what society now wants and what the natural systems can sustain? In the latter case, the key is ecological monitoring, which ensures ecosystem sustainability, including both natural and human communities. Ecosystem sustainability could be ensuring that what was taken out is put back, or some other definition determined by society. Will the northern community of "X" survive, and will the golden eagle survive as a sustainable species? Is either of them important to society in the first place?

Another key element in the adaptive management process is to be able to manage simultaneously at multiple scales. For example, if our desire is to have landscapes that have 10% of the forest in 300 year-old white pine stands, it means that you can't just manage for single stands of 300 year-old white pine. In a 1997 article entitled "The Big Pines..... and the Big Picture," Algonquin Provincial Park's "The Raven" newsletter outlines the fallacy that 300 year-old white pine stands will always remain the same. Foresters have been telling park naturalists for 40 years that the stand is overmature and will eventually convert to maple. "The Raven" reports that this is happening now and that the area should be harvested to retain the unique pine stands in the area. Pines regenerate well with harvesting or burning. The alternative "forest state" is maple regenerating under the shade of dying pine stands. (Anonymous 1997a).

With fire removed from the system, and the future desired condition being the attributes of a 300 year-old pine forest or a 150 year-old Saskatchewan mixed poplar and white spruce forest, harvesting can be the answer at the stand level. Meanwhile, foresters are being told to ensure that 10% of the landscape is maintained as old-growth. This means a reduced harvest area and more intensive harvesting in combination with prescribed burning. This will ensure that some of the 50 year old white spruce will eventually become 150 year-old white spruce.

This can also be applied to Saskatchewan Boreal Forests that exist in Provincial Parks. In order to ensure the maintenance of the integrity of the Boreal Forest, large disturbance in the form of fire or even-aged logging (clear cut) will be required, or tree species such as white spruce and associated biota will not be rejuvenated. Man will ironically be creating new "unnatural" ecosystems in the name of preservation.

Preservation in the form of individual forest stands, with natural and human factors such as fire and logging left out, will not ensure the preservation of the forest ecosystem as a whole. As in Figure 1, the human yolk will cause the "natural" shell of the egg to break, resulting in destruction of the ecosystem. Adaptive management can develop replacements such as careful even-aged logging that will produce future desired conditions such as wilderness and peace. Ironically, public opinion clearly is not in favor of "even-aged" management that may preserve many of the features of our Boreal forests. The learning feature of adaptive management (Figure 3), ecological monitoring, must include community and societal participation in order for us to ensure preservation of our Boreal ecosystems. Ecological monitoring on crown forests must include *strong public and community ownership and active participation of this process*.

THE FOREST ECOSYSTEMS IN SASKATCHEWAN

Saskatchewan is blessed with 35.5 million ha of forest ecosystems (provincial forests) which make up 60% of the province Anonymous (1997b). This does not include about 2 million ha of agricultural crown reserve land and private wood lots that are not presently managed by the Forest Resources Management Act. About 80% of the provincial forest is not presently allocated for timber, whereas about 16% is allocated for timber harvest over the next two hundred years (Figure 4). Only about 23,000 ha of forest are harvested every year, or less than 0.1% of the total.

Although most of the forests in the province are not likely to be ever harvested and can be considered wilderness areas, another 5% of the forest has been set aside for Park uses. This Park percentage in forest ecosystems is 10% south of the Churchill River.

Most of North and Central Saskatchewan is dependent on provincial forests for economic and social well being.

CAN WE IMPLEMENT ADAPTIVE ECOSYSTEM MANAGEMENT?

Implicit in the previous discussion is man's ability to manage based on his need to produce a state of homeostasis or stability. We assume that stability is a possible goal in spite of all natural laws that say that change and entropy is the norm. We create laws, agreements and organizations that are difficult to change. Our manage-

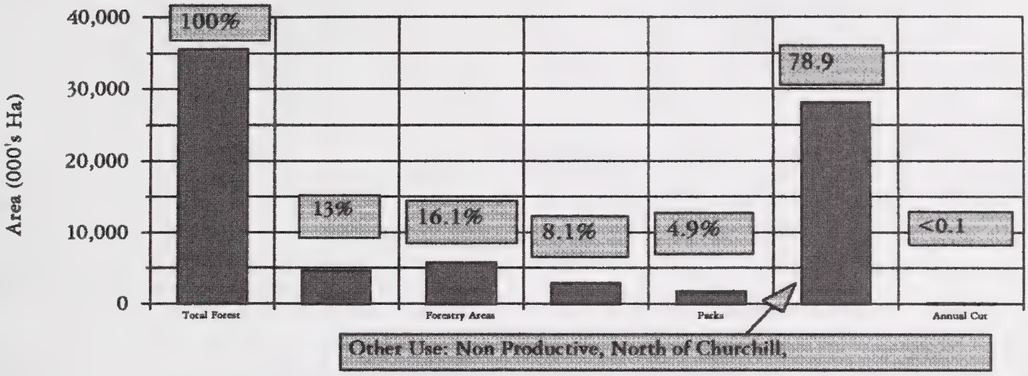

Figure 4. Provincial forest ecosystems in Saskatchewan.

ment objectives are prescriptive and are based on controlling components of the ecosystem. Society's basic ecosystem knowledge is limited and yet the Information Age generates huge amounts of material. As John Lawton said to the American Association of Broadcast Journalist in 1995, "the irony of the Information Age is that it has given new respectability to uninformed opinion" (Crichton 1997). The ugliness of the clear-cut in the Boreal Forest can be used by some special interest groups to raise funds, in spite of the knowledge that it may be the only way to regenerate these forests in the absence of fire. They do not look at these same forests ten years later, fully regenerated and providing critical habitat to many early successional species.

It is clear to foresters that the only permanent destruction of the forest comes in the form of conversion to agriculture, roads and urban development. All of these uses of forest land have general societal approval, yet forest harvesting that maintains the Boreal forest doesn't. Selective harvesting in the Boreal forest is considered the answer for many because the disturbance level is much less than burning or clear-cutting, but most tree species in the Boreal cannot regenerate under that system and it creates many more roads.

In Saskatchewan Crown Forests, the adaptive ecosystem based management system can be applied with the following changes in our approach to management. The key will be the ability of forest managers and society to change rapidly with new knowledge.

Change from Static Prescriptive Objectives

In Saskatchewan's Forest Resources Management Act of 1996, a general framework was developed outlining sustainable forest management. It recognized ecosystem-based management. The subsequent regulations must ensure flexibility in options, or future desired options, and ensure adaptability to new science and societal needs. The Act will focus less on the "how to do" prescriptive control mechanisms, and more on allowing users of the forest, with societal input, to develop future desired conditions that will be flexible with new knowledge. Much of this will be completed by developing guidelines that will be routinely updated, based on what is learned by the adaptive management process. This is in direct contrast to the British Columbia Forest Practices Code that is quite prescriptive and concentrates on the process and fixed enforceable results. In the latter system, change will be difficult.

Single Use Components

In the forest, there are designated wilderness areas, parks, recreation areas and forest management agreement areas. Each of these has a legal element that can be used to encourage the single-use approach. Forest Management Agreements signed in the 1980's ensured wood supply stability for large forest industry investments. Parks and recreation areas were established based on physical values that were there when the park was established. Some early parks and FMA's were established in forests, with little regard for the local communities that once depended on these forests.

Can we take a large geographic area and provide all of these values based on a changing and adaptive ecosystem approach, instead of the single-use approach that is presently occurring? Authors such as Maser (1994) say this is our greatest challenge. Can we have a single "future vision" of the forest that encompasses all these competing components. This would mean one goal for the forest, instead of multiple goals for each of the components which often compete. Figure 5 schematically presents what our management systems look like today. We can not provide effective Forest Ecosystem Management if we are concentrating on developing prescriptions for the "trees" or other components of the ecosystem.

Public Involvement and Public Education

In itself, this is an adaptive process. We started with open houses ten years ago and now we use Cree and Dene translators so that we can actually listen to elders. Without this societal linkage, how can we find out what society wants? Implicit in this knowledge exchange is that the public, particularly the urban public, find out more about Boreal Forests. This will also allow us to understand more about the forest from aboriginal people who have lived there for eons. Their whole evolution was based on adaptive management, which is a hypothesis verified by experience and recorded through verbal communication. Their survival depended on this knowledge.

Through effective public involvement and mutual education, trust will be built, and common forest ecosystem goals will develop that will transcend the individual needs and interests that often only benefit special interest groups.

Understanding the Value of the Forest: Inadequate Funding for Adaptive Management

Often, particularly on public land, short-term benefits from our forests are considered with little regard to long-term sustainability. In Saskatchewan for instance, 300,000 ha of logged-over lands are considered to be not sufficiently regenerated (NSR). What that means is that although there is a new forest regenerating on those sites, it is unlikely that this forest will give to the province the same level of benefit as the initial resource use. In other words, fewer funds were expended to ensure that the white spruce and other species that were logged were replaced.

These areas now are not producing any wood fibre yield, but could have been producing approximately 300,000 meters per year of wood fibre valued at 60 million dollars per year. Of course, that is for the fibre component alone; what about the other values lost due to the altered forest ecosystem?

Reforestation is often the focus of fund shortfalls, but it is only a small portion of the resource commitment Saskatchewan needs for adaptive resource management. Since 1995, current reforestation responsibility has been given to the forest industry as it has been in most other jurisdictions in the world. However, mistakes prior to 1995 leading to insufficiently restocked areas are still the responsibility of the government. Planning, public involvement, audit, ecological monitoring, ecological information, and strategic knowledge gathering are also critical to the elements outlined in Figure 3. Normally, most of these functions are the responsibility of the owner or steward of the resource, which in Saskatchewan is the provincial government.

Deficit pressures and the cost of social programs have made financing the adaptive ecosystem management a challenge; presently, this model is not a reality. The estimates by SERM indicate that a 15 million dollar annual budget will ensure the success of adaptive management in the forest, including addressing the previous NSR problem. The forest industry alone presently contributes 800 million dollars to the annual gross provincial product.

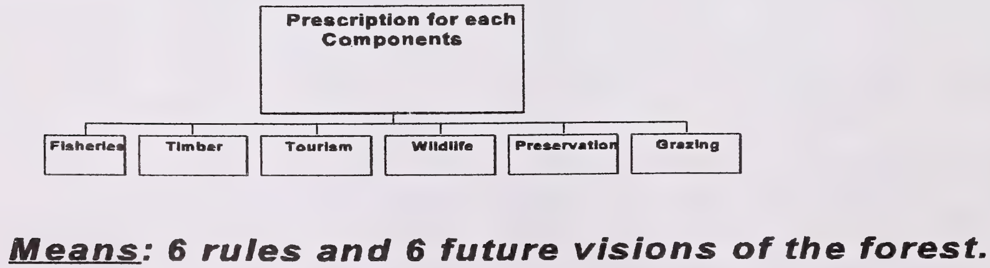

Figure 5. Prescriptions for each of the components of an ecosystem.

When we add to the value of the forest industry the contribution of forested parks, ecotourism, wildlife habitat , the important cultural values of the forest, and hundreds of other benefits that the forest has, it is clear that the value of the forest to the people and the future of Saskatchewan is immeasurable.

Society does not recognize these values and hence there is low relative funding for adaptive ecosystem management. Maser (1994) said that the crux of the problem and the challenge for ecosystem health is society's failure to take responsibility for controlling itself. If we can't invest in ensuring sustainability through adaptive management, we will be doomed to failure. Seemingly, the only time that this lack of effort is noticed is when the resource collapses as it did in the east and west coast fisheries, or when local communities collapse because of resource loss or non-availability. If this happens to our forests, it will take 50 years for them to recover, if they recover at all.

Knowledge, The Vehicle for Improvement

For many years, resource managers in the Boreal Forest have reduced the size of the clear-cut to 35 to 50 ha from 1000's of ha that harvesting or fire used to claim.

The conventional wisdom of the day supported the principle that smaller disturbances would produce more moose. Recent 16 year studies, by Remple, Elkie, Rodgers and Gluck (1997) show that these smaller cuts had little effect on the moose population. Instead road access was the key factor reducing the size of the moose. This definitive study done under the auspices of the timber environmental assessment program for Ontario is one of the few available, but it does point out serious flaws in present wildlife habitat guidelines for Boreal forests which assumed small cuts were good for "featured species", such as moose.

Obviously, few of these longer-term monitoring studies exist, which makes little fuel for adaptive management to change our practices.

Also, even if we do have good natural science and social science studies, how long would it take to change societal perceptions that large clear cuts are potentially ecologically sound for some species? Do we have the mechanisms to change our present guidelines to reflect new realities, and do we have the capability to train our resource managers. In Saskatchewan, unlike British Columbia, we have few existing "forest practice guidelines" to change. However, we have few resources to train our resource managers in new ideas and technologies. Our research and science resources in the province, the keepers and trainers of new knowledge, have been decimated through a decade of constraint.

If our ability to understand and apply new knowledge is limited, our ability to educate the public in forest ecosystems is almost non-existent. Our education system needs forestry courses within both primary and secondary levels, beyond the present modest "Focus on Forests" program that is presently developed as a resource for Saskatchewan schools. Effective public participation depends on it.

Multi-Level Approach

When Aldo Leopold wrote "A Sand County Almanac", it was technically difficult to link his woodlot spatially to landscapes within Wisconsin. Today, with satellite imagery and computer modeling, large landscapes of many forests can be adaptively managed for ecological values and benefits (Baskerville 1985). We can look at all the forest and not just the trees and come up with many options that we can apply and learn. We can relate local options to ever changing regional and global influences.

In Saskatchewan, our past Boreal forests were created principally through fire. Today, fire may not be acceptable to society because it can destroy communities as well as forests, and it feeds massive amounts of carbon to the atmosphere, which likely contributes to global warming. Adaptive management will have to develop local management options that will link with regional and global management needs.

Accountability

It is easy to put the blame of inadequate funding for forest management at the mantle of our politicians. However, it is not that easy when you ask the question to a person on the street in Regina. "Given a choice between funding 15 million dollars out of a provincial budget for forests or for highways or education, where should we put our money?" Forests generally don't even get a blink of consideration in budgets, because the public wants it spent elsewhere, yet forests generate close to one billion dollars of Gross Provincial Product for their fibre production alone.

It is estimated that only 30 to 40 million dollars comes back to the government directly from the crown forest resource. The rest, or 95% of the economic activity generated from the timber resource alone goes to the benefactors of this public resource; that doesn't even count the non-timber benefactors of the forest. Who should pay the other several million dollars needed to manage this billion dollar resource. Society can only hope that this is decided before the resource is depleted to the extent of our ocean fisheries. Once depleted this forest will take a lot longer to come back than the fisheries.

Continual degradation of the forest will slowly but surely erode this benefit base and provide fewer funds for hospitals and fewer jobs for our citizens. It is estimated that over the last twenty years at least 10% of the resource has been lost to single-use activities, poor reforestation and poor fire protection practices.

Accountability for this lack of funding in a democratic society can only be attributed to members of society as a whole, and not to the politicians who only implement what society wants them to implement.

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PROMOTING PRAIRIE STEWARDSHIP ON PRIVATE LANDS

Lesley Hall, Greg Riemer, and Tom Harrison

Saskatchewan Wetland Conservation Corporation, #202-2050 Cornwall Street, Regina, Saskatchewan S4P 2K5

Abstract: The Native Prairie Stewardship Program is aimed at promoting prairie conservation and management on private lands. An initiative of the Saskatchewan Wetland Conservation Corporation, the Program has identified and evaluated remnant native prairie in some of the most highly cultivated areas of Saskatchewan. Surveys from 1995-1997 indicate that 85% of native prairie parcels in these areas are 160 acres or less in size, 51% are in fair or lower range condition, and 94% are subject to threats such as potential cultivation, exotic and woody species invasion, and overgrazing. Landowners of these parcels have been contacted and many have been personally visited. The Program involves interested landowners through a Voluntary Stewardship Agreement, a verbal statement of intent to conserve prairie land. The Program provides information on prairie management and long-term protection options such as conservation easements. In 1997, 135 Voluntary Stewardship Agreements were made on a total of over 26,000 acres of prairie. Through a partnership with the Nature Conservancy of Canada, a perpetual conservation easement is in place on 160 acres of mixed-grass prairie and easements are in progress on 1100 acres of fescue prairie. A test of landowner contact methods indicates that personal visits are a very effective means of enlisting participation in this sort of program. Other work includes production and distribution of a series of native prairie fact sheets and a remnant prairie management planning guide, periodic mailings of a Program update, management workshops, cooperation on enhancement demonstration sites, and assistance with private enhancement work.

INTRODUCTION

The Saskatchewan Wetland Conservation Corporation's (SWCC) Native Prairie Stewardship Program encourages private landowners in highly cultivated areas of Saskatchewan to conserve and manage their native prairie. Through the program, landowners make voluntarily conservation agreements, receive information, and have access to expertise. In 1997, 137 voluntary stewardship agreements were made on a total of over 26,000 acres of native prairie.

Management is promoted through the distribution of relevant information to program participants, such as a program newsletter and a management planning guide. Demonstration projects serve as on-site examples of enhancement work.

Establishing the group of voluntary stewards has involved directly mailing and personally contacting landowners of identified prairie parcels. An evaluation of the effectiveness of different contact methods was performed in 1997 to guide further work in this program and other SWCC initiatives.

BACKGROUND

It is estimated that approximately 17% of Saskatchewan's original native prairie remains (Samson and Knopf 1994). Much of this remaining prairie is concentrated in areas that are considered marginal for annual crop production. Assuming that a much smaller percentage of prairie would be found in landscapes where soils and terrain are ideal for crop production, the Saskatchewan Wetland Conservation Corporation has conducted inventories of these areas for the past three field seasons.

In 1994, 40 rural municipalities where cultivation exceeded 90 percent of the land base were selected for inclusion in an inventory of remaining prairie sites. Potential native prairie sites were first identified on 1:20,000 air photo mosaics and field evaluations of these sites took place in 1995. In 1996, the inventory continued in other highly impacted areas: the fescue prairie, the remainder of the Regina heavy clay soil association, and four highly arable enduring features as determined by the Representative Areas Network (Ecological Land Classification Committee 1994). In 1997, survey work was focused in the fescue prairie region.

In total, the surveyed area covers 13.5 million acres, not including the land in community pastures, Indian Reserves, or water bodies. Just over 134,000 acres of upland native prairie have been identified, i.e., less than one percent of the surveyed land base. Figure 1 outlines the area surveyed by SWCC to date.

At each site, surveyors recorded range site, range condition (Abouguendia 1990, Wroe et al. 1988), dominant and secondary plant communities, the occurrence of rare plants and animals, and potential threats to the remnant. Surveyors also speculated on the factors contributing to the parcel being left uncultivated, such as stoniness or a high water table.

Generally, the prairie parcels in the surveyed areas are very small: 37 percent of the parcels are 40 acres or less in size and only 15 percent are over 160 acres. Direct threats to the parcels are most commonly the potential for cultivation (78 percent), exotic and woody

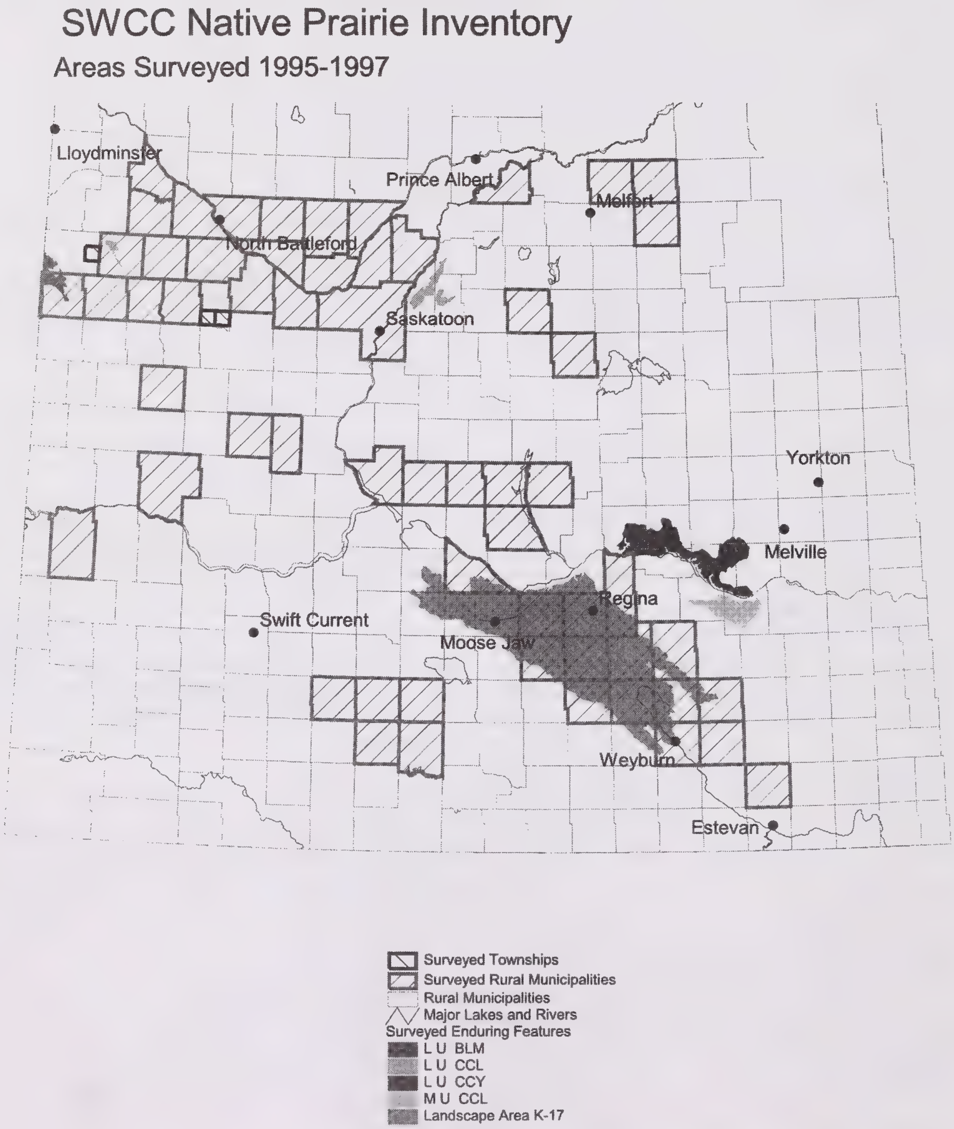

Figure 1. The area surveyed by the Saskatchewan Wetland Conservation Corporation from 1995 to 1997.

species invasion (78 percent) and overgrazing (48 percent). Threats of some kind were recorded at 94 percent of the remnant parcels. Thirty-four percent of the parcels are in poor to poor-fair range condition, while 47 percent are in the fair to good range condition classes.

It is apparent that the long-term existence of privately-owned native prairie within landscapes dominated by cultivation will require a commitment to conservation as well as to management and enhancement efforts. This commitment must be made not only by government and conservation agencies, but by private individuals. SWCC's Native Prairie Stewardship Program is addressing this situation in a variety of ways.

PRIVATE STEWARDSHIP

The main intent of the Native Prairie Stewardship Program is to promote the health and integrity of privately owned native prairie in Saskatchewan. The program is attempting to promote "conservation-minded" values and behaviour in a large and diverse group of landowners by increasing their knowledge of, interest in, and commitment to prairie ecosystems and their management.

The basic information package for the program consists of a brochure and eight fact sheets dealing with a variety of native prairie issues, including grassland ecology, wildlife, archeological and heritage resources, seed harvesting and marketing, and conservation easements. The information package information has been distributed to 1500 identified prairie landowners and many interested agencies.

The Voluntary Stewardship Agreement

The Native Prairie Stewardship Program encourages landowners to make a commitment to prairie conservation. This is loosely formalized through the "Voluntary Stewardship Agreement," which is a verbal commitment by the landowner to maintain and conserve the prairie in question, inform us of any major land use changes that might impact the native prairie, and inform us of the intent to transfer ownership of the parcel. The agreement is purposefully simple and informal to emphasize that it is the landowner who carries the onus of the commitment and who has control over land management decisions. In other words, we are not policing their actions.

This type of agreement also includes a group of people who may be excluded by more stringent conditions. While the agreement is not binding and does not confer legal protection to the land, relatively few people are willing to put restrictions on the future use of their land, whether the restrictions be on themselves or a subsequent owner. The great majority of the landowners we have contacted are to some extent indifferent to conservation. They may lean toward conservation-minded thinking, but not be deeply committed to it on a personal level. It is this majority that would likely not be involved in a strict set-aside program, signing a conservation easement, or donating land to a conservation agency. However, they *are* interested to some degree in conservation and management - they are interested enough to agree to be voluntary stewards and to take advantage of information and expertise that they can access through the program. This is a large constituency of people who have demonstrated an interest in enhancement and management and who may become committed conservationists.

For the most part, stewardship agreements have been established after personal visits to prairie landowners. Several landowners were initially contacted in 1996 and further visits have been ongoing from March 1997. To date, SWCC staff have visited 267 native prairie landowners. Of these, 137 landowners have made a Voluntary Stewardship Agreement. This amounts to the securement of over 26,000 acres of native prairie. Twenty-five of the landowners have also expressed an interest in conservation easements.

A certificate of recognition, signed by the Minister Responsible for SWCC is sent to each voluntary steward. In addition to acknowledging the worth of the landowner's stewardship efforts, the certificate adds weight to the verbal agreement. The certificate is the piece of paper that confirms participation in the program; it is a subtle way to reinforce the commitment. A sign is also available to interested stewards. The sign, like the certificate, offers substance to involvement in the program and the value of the prairie land. It also creates awareness and recognition of the program in the wider population, perhaps most importantly among neighbours.

Although the basic thrust of the program is to encourage Voluntary Stewardship Agreements, landowners are also informed about conservation easements as a potential tool to meet their conservation needs. SWCC has partnered with the Nature Conservancy of Canada (NCC) to negotiate conservation easements on remnant native prairie lands. Through the cost sharing of a full time position with the NCC, a perpetual easement has been put in place on a 160 acre mixed-grass prairie site, and easements are in progress on 1100 acres of fescue prairie owned by voluntary stewards initially contacted through SWCC extension work.

Promoting Land Management

The results of the prairie inventory demonstrate the necessity of enhancement and management to the long-term persistence of native grassland habitat. Because of this, motivating management planning is a major goal of the Native Prairie Stewardship Program. The voluntary stewards are a defined group to whom programs, publications, and workshops promoting conservation management can be directed.

One example of conservation management promotion is a program newsletter which will be mailed out on a quarterly basis. The newsletter will contain articles of relevance to prairie land managers, including profiles of other voluntary stewards and their work. There will also be opportunities for landowner feedback in the form of questions or story ideas.

SWCC has also produced a management planning guidebook, *Managing Your Native Prairie Parcel* (Moen 1997), that contains basic information about native prairie ecosystems, as well as their conservation and management. The book contains a self-directed guide to developing an adaptive management plan, beginning with the identification of what the individual values about the prairie land. In its draft stage the guide was critiqued by several external reviewers, including 16 voluntary stewards who represented the book's target audience. The feedback from the landowners was invaluable, and including these people in the review process reinforced the program focus on landowner involvement.

The management guide will be distributed to the voluntary stewards, as well as to partner agencies. Several management planning workshops will be held in conjunction with its distribution. Stewards will be encouraged to complete their own management plans, and to seek advice and input from us if they are interested. We hope to assist many of these individuals by providing some of the materials they require, such as fencing or seed. Ideally, this will be set up as a program to which landowners make applications and are assisted based on the potential impact of the plan on their land.

In addition to these publications, management and enhancement demonstration sites are being developed to provide examples of land enhancement projects. SWCC and the Grazing and Pasture Technology Program (GAPT) are involved with three landowners in range improvement demonstration projects in the Biggar area. The landowners are interested in improving the range condition and health of their native fescue prairie pastures, which collectively amount to 1500 acres. In the spring of 1997, 225 acres of marginal cropland were converted to tame forage for additional pasture and five kilometres of fencing were built to allow grazing rotation. The landowners have signed agreements to maintain the tame forage for at least 10 years and GAPT staff will monitor the range condition over the next several years.

Such a project serves as an example of what sound range management can accomplish. Walking in a healthy pasture and hearing a testimonial from a neighbour can strongly reinforce the message of conservation management publications.

LANDOWNER CONTACT

As already mentioned, stewardship agreements have been established through personal visits to the landowners initiated by SWCC staff. In order to evaluate the effectiveness of various approaches to contacting landowners for involvement in a stewardship program, much of the landowner contact work has been framed as an evaluation.

Evaluation of Landowner Contact Methods

A study was set up to apply various types of contact approaches to 400 prairie landowners. Four groups of 100 were established and subjected to different treatments. Efforts were made to control for site proximity to urban centres and relative north/south location. The treatments involved direct mailings and personal visits.

Members of group one were mailed a letter inviting a response with an included postage-paid response card. Those who did not respond to this first letter were sent a second letter five weeks later. Rather than including a response card, the second letter invited a response via a toll free telephone number.

Members of group two were sent a letter identical to the first letter sent to group one, although the group two letters included a toll free telephone number rather than a response card. If no response came from group two landowners, a phone call to arrange a visit was made.

Groups three and four received no letters. Rather, group three was phoned to arrange a visit and group four landowners were visited with no previous phone call (drop-in visits). The test has been largely completed, although over 60 of the landowners contacted have not yet decided whether or not to make a stewardship agreement.

Response to Direct Mail

Response to the mail-outs varied from 2% to 11%. The response rate was highest (11%) to the first letter sent to group one, which included a postage-paid response card. The card asked respondents to indicate their interests, and it is important to note that only 5 of the 11 respondents indicated an interest in the program itself. This treatment is directly comparable to the first letter sent to group two, which included a toll-free telephone number and had a lower response rate of 2%. The second letter to the 89 group one members who did not respond to the first letter motivated four additional people to respond (4.5%).

Analysis with a chi square test of the response to the first letter indicates that a significantly higher response rate occurred with a postage-paid card than with a toll-free number ($P<0.01$). When the first letter treatments are considered in terms of interest type, however, there is no significant difference in how many respondents indicated a desire for more information on the stewardship program (5% from group one and 2% from group two).

Considering the group one treatment of two letters in combination, the 9% response of those indicating interest in the program is significantly different from the 2% response to the group two treatment of one letter ($P<0.05$).

Overall, direct mailing prompted 2% to 9% of the sample population to express an interest in the program. This response rate is much lower than the interest generated by personal contact.

Response to Personal Contact

Due to time restrictions, attempts to contact all 100 people in groups two, three, and four were not possible. The numbers of people we attempted to contact in each of groups two, three, and four were 83, 95, and 75, respectively.

Response to all of the personal contact methods was very positive. While not all of those contacted have decided whether or not to participate, the preliminary data have been analysed using a chi square test. Presently, there is no significant difference among treatment types in the percentage of initial "contacts" (defined as talking to the owner by phone or in person without fully discussing the program) that result in voluntary stewardship agreements (from 46% to 50%) versus those contacts which do not (including undecided contacts).

Differences are apparent in other respects, however. First, the number of actual discussions about the program ("visits") that occur after the initial landowner contact is proportionally higher in the drop-in visit treatment (87%) as compared to the visits that result from a phone call (60% in group two ($P<0.001$) and 64% in group three ($P<0.005$)). Second, proportionally fewer voluntary stewardship agreements result from drop-in visits (53%) than from pre-arranged visits (83% in group two ($P<0.005$) and 76% in group three ($P<0.025$)).

Based on the preliminary results, then, out of a hypothetical 100 initial contacts each treatment type could be expected to result in an average of 48 stewardship agreements. In the phone ahead treatments, however, on average only 62 of the 100 initial contacts would lead to a full discussion of the program, as compared to 81 visits out of 100 drop-in contacts. In other words, the pre-arranged visits have a much higher success rate in terms of stewardship than do the drop-in visits.

It appears that phoning ahead may act to filter out people who are not interested in the program before the visit occurs, but overall stewardship rates are not correlated to the initial contact type.

Because the contact method appears to be of little consequence in terms of effectiveness (i.e., landowner participation in a stewardship agreement), the contact approach can be based on its efficiency. For example, because sending a pre-visit letter does not appear to increase participation rates, the added costs make this approach inadvisable. Similarly, because there is no difference in participation rates between contacts made by phoning or by dropping in, the visits can be pre-arranged or not in order to maximize time-use in the field, without concern that one method would be more effective.

Through the test process to date, 109 voluntary stewardship agreements have been made. In other words, close to half of those contacted by phone or in person made a commitment to conserve their prairie, while 24 percent were unwilling to enter into a stewardship agreement. Overall, preliminary results indicate that personal visits are a very effective method of encouraging stewardship.

Another finding regards the information packages that had been sent to all of the landowners in January/February 1997. This was the first contact the landowners had with the Native Prairie Stewardship Program. During the test process, records were kept of whether or not the landowners remembered receiving the package. Only 66 of the 182 asked (36%) remembered the package. While records were not kept on whether or not these 62 read the information or how they felt about it, many indicated that they remembered something coming in the mail or recognised the fact sheets when they were shown to them, but few seemed to have read the information thoroughly. However, many people who did not recall the package did become stewards after a personal visit, and were interested in reading the fact sheets and other information about native prairie we offered. This leads to the recommendation that personal contact should precede direct mailing whenever possible. Other methods of raising awareness of a program, such as media stories or signs, could potentially increase the effectiveness of mail-outs as well.

Future evaluation will focus on the effectiveness of phone-call visits relative to the face-to-face visits that were performed this season. The cost savings that phoning offers may make this a valuable option. In future, a survey can evaluate the success of each of these methods in terms of behavioural and attitudinal change. Continual re-evaluation of which methods work (and which do not) and which goals are being achieved (and which are not) is vital to effective conservation program delivery.

CONCLUSION

Much of the scarce native prairie habitat that remains in the highly cultivated areas of Saskatchewan is privately owned. SWCC survey work has shown that the great majority of these privately owned parcels are small and threatened by cultivation or inappropriate management. Conserving remnant prairie areas requires that these facts be addressed. The Native Prairie Stewardship Program aims to work with rural landowners to raise awareness about prairie conservation and management and to encourage stewardship values.

Attempting to encourage certain attitudes and behaviours, while leaving decision-making in private hands, requires that the landowners become involved and interested in learning new information. In order to promote this process, SWCC is involving landowners in a conservation program, and this group is being provided with information and enabled to exchange information. In addition, enhancement work is encouraged through provision of resource materials, examples and demonstrations, and monetary and technical assistance. Personal contact with landowners has proven to be a very effective means of encouraging stewardship.

While a voluntary agreement does not offer legal protection, a wide variety of people, beyond those already deeply committed to conservation, are willing to make this type of informal agreement. The long-term impacts of increased understanding and awareness of prairie conservation issues that can flow from the voluntary involvement in the program should not be underestimated. Neither should we underestimate the ability and willingness of private land managers to conserve and enhance natural habitat.

ACKNOWLEDGMENTS

The Saskatchewan Wetland Conservation Corporation gratefully acknowledges funding support for the Native Prairie Stewardship Program from the following partners: Agriculture Institute of Management in Saskatchewan; Canada-Saskatchewan Agriculture Green Plan Agreement; Environment Canada - Action 21; National Fish and Wildlife Foundation (US); Saskatchewan Environment and Resource Management, and; Wildlife Habitat Canada.

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CONSERVATION AND AGRICULTURE

KEYNOTE LECTURE: A BRIEF SUMMARY OF HOLISTIC MANAGEMENT

Noel McNaughton

3438 Point Grey Road, Vancouver, British Columbia V6R 1A5

Abstract: This paper is a discussion on adaptive management as a central component of the holistic management approach. Holistic management requires creating a vision for the land base and the land manager(s), choosing management tools, monitoring their results and adapting use of different tools to achieve success. Methods to test proposed actions against the goals are integral to Holistic Management.

A SUMMARY OF HOLISTIC RESOURCE MANAGEMENT

Holistic Resource Management is a simple (but not necessarily easy), common-sense, yet revolutionary, decision-making "mental model." One can start at almost any point in the decision-making "cycle," but it is described here in order from "defining the whole" to "monitoring actions."

"Holism" is the theory that with any organism, or "whole," the whole is greater than the sum of the parts. The theory of holism also suggests that the universe does not consist of separate "things," but rather sets of patterns or relationships, each of which is a "whole." The universe is really a multitude of wholes within wholes, so it follows that consciously managing "wholes" is likely to be more successful than managing parts in relative isolation from each other.

DEFINING THE WHOLE

Any group, association, business or organization must define the "whole" it is working with, or managing. For ease of definition, it is useful to consider various aspects of the whole separately:

People: This aspect of the whole identifies the people actively involved in the decision- making of the whole being worked with. In a business, the "people" referred to here would be the owners, managers, employees and board of directors.

Resource Base: This describes the resources available for sustaining the production or activity of the whole. In a land-based organization such as a farm, the resource base is mainly the land owned by the farm. A community agency might have as a resource base the goodwill of the government body that supports it, plus the "clients" the agency serves. A retail store's resource base would be its physical plant, plus its customers and suppliers. Without one or the other, the organization would likely disappear. Another aspect of the resource base for any entity is the ecosystem itself, which is the only "sustainable" capital any society has.

Money: This aspect describes the money the people have to work with, both that on hand and the income they can generate, as well as any credit available, in order to operate.

THE HOLISTIC VISION/GOAL

Once the "whole" is defined, a Holistic "Goal" or "Vision" must be formed that will guide the business or organization in what it does (Figure 1). It is important that all the people involved in running the organization have an active voice in forming this vision. Holistic Management is collaborative, not hierarchical. It is also critical that the vision only describe what the people want, not how to get it. (The "how to's" of carrying out the vision are determined with the help of the testing guidelines, described further on.) This vision has three aspects, which simply put are:

Quality of Life: What the people in the whole want out of life, based on the values they choose to live and operate by. An organization might begin with a written "statement of purpose," and go on to describe the values the people want to express in their working relationships with each other, the principles the organization wants to operate by, the physical working environment desired by the people, and so forth (Figure 2).

Production: What they must do to achieve what they want, including the nature of the activity they will do for money or income, and what they must do to create or achieve the other aspects of their quality of life vision. (e.g. if they want to have harmonious working relationships,

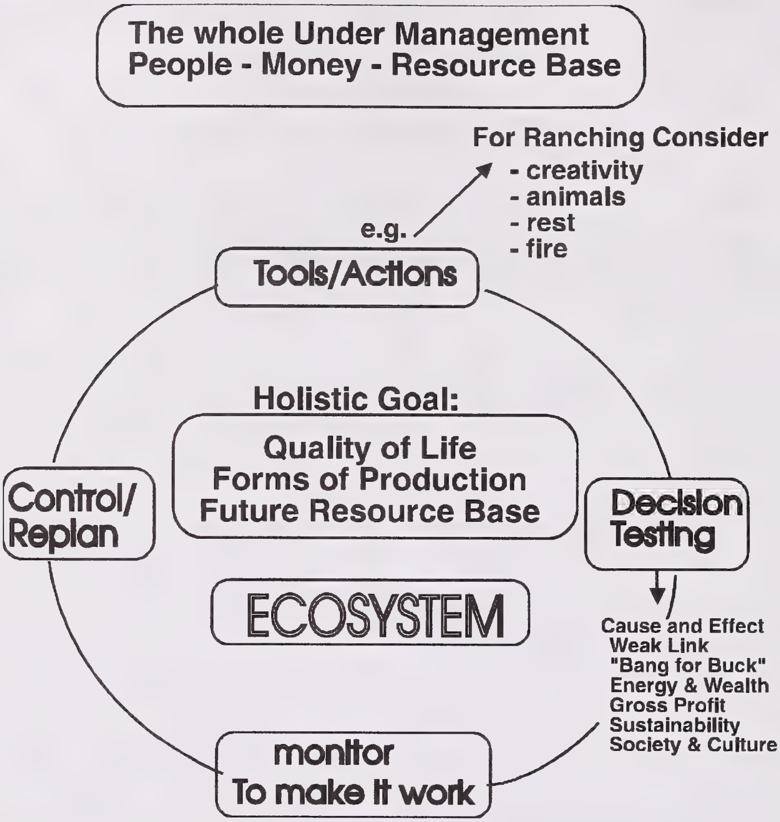

Figure 1. Because predictions and expectations vary depending on where the boundary for a whole is drawn, it is important to include as many of the functional components as possible. In the above scenario, the whole recognizes the basic ecosystem from which life and energy is derived, it includes the most important elements of the human cultural system and a response system based on adaptive management. The cultural system embodies expectations of quality of life, appropriateness of forms of production and the degree of resource capital that is expected at the end of a use cycle (living off of interest, or the capital). The adaptive management scheme analyses the signals of the system and replaces tools and actions as necessary to satisfy the considered goal.

they will have to "produce" an atmosphere of trust, respect and acceptance.)

Future Resource Base Description: A written description of the condition their resource base must be in to sustain production forever. In a land-based enterprise such as a farm or public land, this aspect of the vision will describe the condition the ecosystem of the land being managed must be in to sustain the desired production forever. Other enterprises or organizations will describe the way they must be perceived by their supporters or clients and suppliers in order that the organization will continue to receive continued support. A community might describe the layout, infrastructure and condition the ecosystem (water, soil, diversity of plants, insects and animals) in the town, as well as the surrounding hinterland must be in for a healthy and thriving community far into the future. This part of the vision may also include people (e.g. clients or customers), but these are not the "people" who make decisions and manage the organization. All organizations and businesses, whether they own land or not, must have a general statement describing the desired condition of the ecosystem in and around their community, and perhaps expanding to their province, nation or even the whole world. This may sound grandiose, but the fact is the decisions we make as we go about our everyday lives (the kinds of purchases we make, the vehicles we drive, even the food

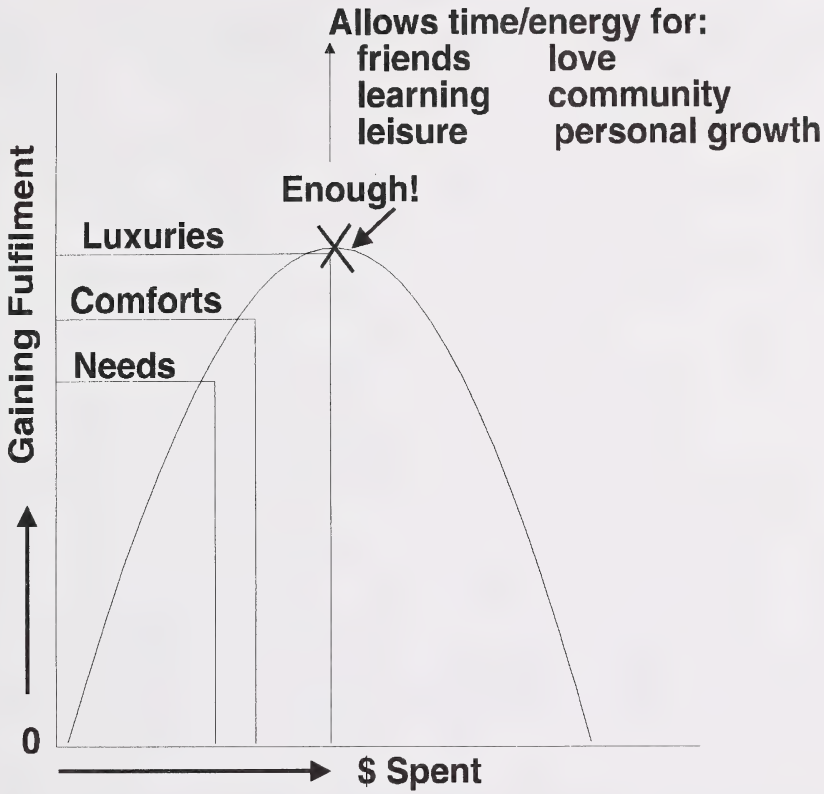

Figure 2. The relationship between material consumption (standard of living) and personal fulfilment is curvilinear. Because additional spending initially results in substantial increases in fulfilment through satisfying needs, more spending (material consumption) provides less fulfilment as one moves into comforts, and even less when one is purchasing luxuries, until eventually each additional dollar spent gives less fulfilment than the last one. The top of this curve is called "enough". Further fulfilment now will come from non-financial means such as family, friends, community and so forth. Continuing to spend past the point of "enough" will lead to more time spent working, more stress and less of the other things that provide fulfilment.

Adapted from: "Your Money or Your Life" by Joe Dominguez and Vicki Robin, Viking 1995.

we eat) has an impact on the ecosystem, and ultimately a healthy ecosystem is the only true capital that sustains civilizations.

Once this Holistic Vision/Goal is written, even if it is only temporary (which it will be for at least a few years after an organization begins managing Holistically), it is the beacon toward which all action is aimed.

THE TESTING GUIDELINES

To ensure all actions take the organization toward its Holistic Vision, Holistic Resource Management employs a series of evaluative decision-making questions called "Testing Guidelines." There are seven guidelines, designed to analyse each proposed action to ensure it is simultaneously socially, financially and ecologically sound.

Cause and Effect

The question asked in this test is: "will the action (or tool) we are testing address the cause of the problem we are dealing with, or is the problem a symptom of some other cause?" This is the first test to turn to when a problem is being addressed, especially if it has been dealt with before. Tremendous effort is spent every year all over the country by organizations trying to solve problems, but the problems keep getting worse because the action taken is really addressing symptoms. This test is designed to help address causes of problems, which usually take longer to solve, but do not return.

Weak Link

There are three aspects to this test: Social, Biological and Financial:

Weak Link #1: Social: This aspect of the test simply says "If you take this action will you encounter or create a blockage to progress?" The idea is to pay attention to the social aspects of any decision being tested so that you are less likely to do something that looks good on paper but creates "people problems" down the road.

Weak Link #2: Biological: The question posed here is: "Does this action address the weakest point in the life cycle of this organism?" This test applies in situations where a problem regarding a living organism is being addressed. The problem may be too many organisms (weeds in a farmer's field, an increasingly virulent strain of bacteria in a hospital), or too few (an endangered species). In either case, the weakest part of the organism's life cycle (the cycle from birth, through growth, reproduction, death and decay) must be identified, and the action being tested should be applied at the weakest part of the life cycle.

Weak Link #3: Financial: "Does this action address the weakest link in the chain of production?" Every organization has a series of steps or links in carrying out its work, whether it is the process used in developing new policies, or in manufacturing products. One "link" in this "chain of production" will always be the weakest at a given moment, and the idea of this test is to question whether the action being tested addresses that weakest link. This is particularly important during financial planning for the coming year.

Marginal Reaction

The question asked about the action being testing here is: "In which action should I invest each additional unit of money, or time and labour, to provide the greatest progress toward the Holistic Vision?" This test always requires two or more actions to compare. This test is simply a reminder to think about where the organization's effort is going so it gets maximum performance toward the Holistic Goal with every action taken.

Energy/Money | Source and Use

There are two aspects to this test, which is designed to remind the organization where it is getting the money and energy from (the "source") to carry out a given activity, and what it is doing with the money and energy (the "pattern of use") relative to the Holistic Goal. This test may sound complex, but in essence it is quite simple.

The Source of Energy or Money. The questions asked in this part of the test are: "Is the source of energy constant or finite, benign, or potentially damaging? Is the source of the money internal or external?"

Keeping in mind its Holistic goal, an organization must always be aware of its effect on the ecosystem, the foundation supporting all civilizations. This question reminds it of that. It is also a reminder to be aware of the "source" of the money being used to carry out activities. "Internal" money (profit or income generated through business activities) is far more stable and less risky than "external" money (e.g. loans, grants).

The Pattern of Use of the Energy or Money. The questions asked in this second part of the test are:

1. "Will the use being tested provide infrastructure to assist in reaching our Holistic goal?" Building infrastructure, such as buildings, roads, sewer systems, equipment and myriad other things, including gaining knowledge, requires investments of energy and money, not to mention time. But once something is built, or knowledge acquired, it presumably does not need to be done again. Although it is always preferable to use internal money and benign energy, building infrastructure is the least risky *pattern of use* for external money and potentially damaging energy, as it is a one-time expenditure that gives long-term service.

2. "Is the use being tested once-only, or consumptive, with no lasting effect toward achieving the Goal. (i.e. If used again, will the same expenditure of energy or money have to be incurred?") A typical example of consumptive use is burning of gasoline to run a vehicle and the purchase of that gasoline. Every time the vehicle is used, more energy (and money) are required. For consumptive uses benign energy and internal dollars should be used as much as possible. At the moment, almost all internal combustion engines run on petroleum fuel which is both non-renewable and damaging to the ecosystem.

3. "Is the use being tested cyclical, in that once invested no further inputs of money or energy are needed?" An example of a cyclical pattern of use might be the purchase of photo-electric cells as a source of electricity. Once the energy is expended to create the

cells, and the money spent to purchase them, no further expenditures are necessary, and the cells go on working indefinitely. This is a less risky pattern of use of finite energy and external money, as just like building infrastructure, it is a one-time expenditure that gives long-term service.

4. "Is the use being tested addictive, so that once you start using the energy or money this way, you risk becoming dependent on it in the future?" One of the main causes of addictive patterns of money and energy use is addressing symptoms rather than underlying causes of problems. The longer a symptom is addressed the worse it becomes, and the more the organization can get "hooked" on spending money and energy on it. Government subsidies and grants can be addictive as well, again because people can become dependent on them and have business decisions skewed by whether they help the organization qualify for more subsidies.

Again, this test simply says to be aware of the "source" of the energy and money being used, and the "pattern" of how it is used.

Gross Profit Analysis

Profit is necessary to run any business, and in Holistic Management profit is part of a business's Holistic Vision. In conventional thinking production is generally the goal or objective and profit is often used as a test. The testing, which you are probably getting the idea of by now, is to ensure that all actions to yield that profit are socially, environmentally and economically sound. The best way to evaluate which enterprises have the highest profit potential is to do a Gross Profit Analysis on all enterprises to detect those which provide the most income over variable costs to provide for covering overheads and the excess required for profit. The Gross Profit Analysis referred to here "does not include fixed costs." In conventional economics, this test would be called "Contribution Margin." The reason for leaving out fixed costs is that they can distort the financial picture, as it can be difficult to attribute fixed costs to each enterprise equitably. As the organization will be paying fixed costs (overheads) anyway, they are simply left out of the calculations in order "try to determine which enterprises produce the most money (Gross Profit)" to pay the overheads with. In using this Test, one simply estimates the income that will be produced by carrying out a given enterprise and deducts the extra money that will have to be spent to carry it out. The difference is the Gross Profit, which is available for paying overheads, with presumably some for profit as well. The more enterprises with high Gross Profit an organization has, the more likely it is to be profitable.

Whereas other tests are used in most decisions and are done as mental exercises, this test is always pencilled, done in great detail and only used when selecting and looking at the performance of enterprises, usually once a year during financial planning.

Sustainability

This Guideline simply asks whether the action being tested will lead toward or away from the future resource base described in the Holistic Goal.

Society and Culture

This Guideline is used last as it builds on the mental picture formed from going through the other six tests. There is one exception to this order: in financial planning following brainstorming new sources of income, Society and Culture is the first test used to evaluate new sources being considered. Where the other six tests concern themselves with facts about the tool or action being tested, this one asks how the people involved "feel" about it. The question asked here is: "Does this action truly take us in the direction of the Quality of Life we seek. Does it fit with our values? Does it negatively affect anybody else's Quality of Life?" This test can keep an organization from using tools or taking actions that it may profit from, but that offend or injure others. Activities that cause pollution or violate community social norms would fall into this category.

MONITORING

Even though a proposed action may have passed all the Guidelines and so appear to take the organization toward its Holistic Vision, there still may be an error in thinking somewhere along the line, so the result of implementing the action is "monitored continually" in order to observe what actually happens. If the monitoring shows that the desired results are not being achieved, the action is stopped, the situation re-examined, re-planned, and new action tested, and the process carried on. This monitor-control-replan loop helps ensure the organization is always moving toward its Holistic Vision, as that Vision describes everything the organization exists for.

ORGANIC FOOD PRODUCTION

Ron Schriml
Colony Foods, Box 454, Bruno, Saskatchewan S0K 0S0

Abstract: This presentation will look at the possibilities and limitations or organic agriculture as currently practised on the Prairies using Organic Crop Improvement Association Chapter #5 as one case study. The experience of farmers in this Chapter located in the Aspen Parkland Ecoregion suggests that organic agriculture has some potential to be less harmful to the prairie ecology, but that without development of the human communities, particularly the local economies within these communities, particularly the local economies within these communities, organic agriculture with its current participation in the global economy can be nearly as destructive of species and habitat as conventional agriculture.

Development of "sustaining" communities that support in economic, social and spiritual ways the values of tending to each other and tending the land is proposed as the most important "sustainable development".

PRAIRIE BIODIVERSITY CONSERVATION - THE RANCHING CONNECTION

Lorne Fitch
Alberta Environmental Protection, 625 18th Street S, Lethbridge, Alberta T1J 3E9

Barry Adams
Alberta Agriculture, Lethbridge, Alberta

Abstract: This paper represents a philosophical discussion of the role of ranching in maintenance of prairie biodiversity. We explore the historical role of prairie ranching in co-existing with, and maintaining, much of the prairie that remains ecologically intact. We examine the principles of prairie ecosystem management and explain the role of ranching in maintaining ecological processes. The principles of range management are reviewed to determine their foundation for ecologically based grazing strategies. A synopsis is made of where we are today in terms of ranching achieving biodiversity goals. A number of problems and issues are discussed to help establish the status of today's ranching operations. Based on that status, we provide some of our recommendations on where we need to be collectively to assure the future ecological integrity of prairie and the involvement of ranchers in that goal.

HUMAN EXPOSURE TO HERBICIDES

Allan J. Cessna

Agriculture and Agri-Food Canada Research Centre, Lethbridge, Alberta
Current address: National Water Research Institute, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5

Herbicides are generally synthetic organic compounds used to control unwanted vegetation or weeds. Application may either be directly to plants or soil to control unwanted terrestrial vegetation, or to water bodies to control aquatic weeds. Herbicide use plays an integral role in most crop production systems and agricultural production accounts for the greatest use of herbicides. However, significant amounts of herbicides are also used in the forestry industry and to maintain pipeline, powerline and highway rights-of-way. As well, significant use also occurs within the urban setting to control weeds in lawns and gardens, and to maintain parks and golf courses.

It is now well established that herbicides can undergo chemical modification following application and that not all of the herbicide remains within the area to which it was applied. Herbicides undergo microbial or chemical degradation in soil, metabolism/conjugation in plants, and photodegradation by sunlight. As illustrated in Figure 1, transport mechanisms by which herbicides or their metabolites/degradation products can move off treated areas include droplet and vapour drift during application, post-application vapour drift or volatility losses from plant and soil surfaces, and wind erosion of treated soil. Such atmospheric inputs are later removed either by dry (particulate) deposition or through rainfall washout. Transport into surface waters occurs with snowmelt, rainfall or irrigation runoff from treated land. Contamination of ground waters can occur via leaching and preferential flow of herbicides under both dry land and irrigated agriculture. Herbicides and their metabolites may also be removed from treated areas as residues in edible portions of crops.

In general, there are two types of human exposure to herbicides. One is occupational exposure and generally involves either those manufacturing/formulating herbicides or those applying herbicides (farmers, professional applicators). The other is non-occupational or environmental exposure and involves the general population. Herbicides generally express low to moderate toxicity to mammals, birds and fish.

The presentation discussed environmental exposure of humans to herbicides/metabolites/ degradation products based on data from several studies carried out by the author. Inhalation exposure from breathing contaminated air was discussed and ambient concentrations of herbicides detected in air at several sites in Saskatchewan presented. As well, dermal exposure due to atmospheric deposition on the skin, use of contaminated water and contact with surfaces contaminated by atmospheric deposition were discussed, and data indicating the magnitude of dry and rainfall deposition at several Saskatchewan sites presented. Finally, oral exposure due to drinking contaminated water and ingesting herbicide residues in edible portions of crops was discussed. Data indicating the magnitude of herbicide residues in Saskatchewan farm dugouts used as potable water supplies were presented in relation to the Canadian Water Quality Guidelines for Drinking Water and the leaching and preferential flow of herbicides to ground water discussed. The magnitude of herbicide residues permissible in crops by Health Canada were also discussed.

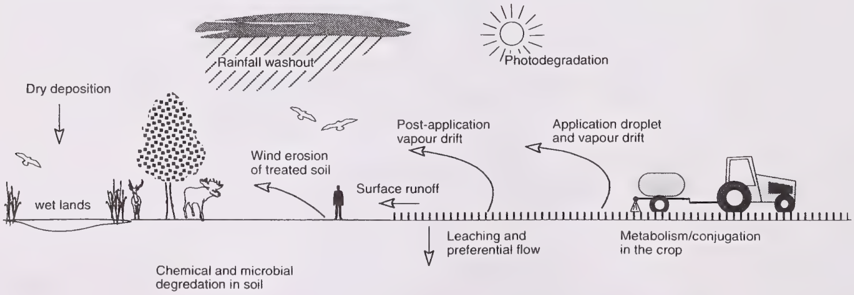

Figure 1. Herbicide degradation processes which occur following application, and transport mechanisms which remove a portion of the herbicide application from the treated area.

BIOTECHNOLOGY, BIODIVERSITY AND CONSERVATION

Wilf Keller

Natural Research Council, 110 Gymnasium Place, Saskatoon, Saskatchewan S7J 5B6

Abstract: Biotechnology and, more specifically, genetic engineering have emerged as a result of the tremendous research advances made in biology and genetics over the last quarter century. Methodology for genetic engineering has been developed for more than 50 of the world's important crop species and commercial cultivars have thus far been developed for approximately a dozen crops. In Canada the greatest advances with transgenic crop technologies have been achieved in canola with approximately one sixth of the 1997 acreage devoted to the cultivation of transgenic, herbicide-tolerant cultivars.

While many of today's commercial products of crop biotechnology possess modified agronomic trains (such as herbicide resistance) which are of direct value to the producers, in the future we should expect a much wider range of applications and products of biotechnology. In the next century, plant biotechnology will contribute to the development of sustainable and environmentally friendlier approaches for food production and processing. Plants will be increasingly relied upon for the production of pharmaceutical and industrial products. Genetically modified plants will also be useful in a wide variety of soil and water bioremediation processes. The rapidly growing knowledge base relating to the genetic and biochemical properties of species and their interactions will contribute to maintenance of biodiversity on the planet. Improvement in the quality of agricultural ecosystems should also be realized.

THE NEW LANDSCAPE: AGRICULTURE AND WILDLIFE

Lee Moats

Ducks Unlimited Canada, Box 4465, Regina, Saskatchewan S4P 3W7

Abstract: Wildlife conservation efforts have focussed heavily on extracting land from use by the dominant agricultural industry on the Prairies. This strategy, while effective at the local level, is having limited effect at the regional level in maintaining the productive capacity of the landscape for wildlife. The reason is a combination of high cost and continued expansion of intensive agriculture on the landscape.

A new vision is required to save our natural heritage. This vision has to find solutions for wildlife within the agricultural context instead of outside agriculture. Wildlife programs have to become more oriented toward the people on the landscape, who control it, instead of just on the land itself. Habitat indicators need to be related to indicators of agricultural sustainability, leading to habitat becoming an agricultural objective instead of just a wildlife one.

KEYNOTE LECTURE: THE DICHOTOMY BETWEEN ENVIRONMENT AND ECONOMY: IS A MEANINGFUL MEETING OF THE TWO POSSIBLE UNDER THE SUSTAINABLE DEVELOPMENT UMBRELLA?

Clifford Lincoln, MP

Chairman, Standing Committee on Canadian Heritage, House of Commons, Confederation Building, Room 130, Ottawa, Ontario, K1A 0A6

In the fall of 1987 I was very privileged to be part of the Canadian delegation at the United Nations when Mrs. Gro Harlem Brundtland presented her famed report "Our Common Future". The first speaker after Mrs. Brundtland was somebody very few of us had ever heard about. His name was Mahmood Abdul Gayoom, the President of the Maldive Islands. We were hoping his speech would be very very short, so that we could soon hear Prime Minister Rajiv Ghandi of India (who has since died in tragic circumstances), and President Robert Mugabe of Zimbabwe. But I can tell you that after two minutes of listening to President Gayoom, you could have heard a pin drop. He described his island-archipelago as sparkling jewels on a cushion of blue which is the Indian Ocean. For generations his people had lived in peace with nature. Then, suddenly, in the 80's, they were visited by tremendous waves, tidal waves, the first set of which came as a shock and caused havoc on the islands. The second set of tidal waves was worse, and the third time the waves caused tremendous destruction, and brought with them injury and death. He pointed out that in the next century scientists were warning that the seas might rise between 1 and 3 meters. "What happens if it's the average of 2 meters?", he asked. "My island-nation would then disappear under the sea forever." And he proceeded to ask us these questions at the United Nations: "What have we done to deserve this?" and "Why should we be the victims, we who have no plants that spew greenhouse gases into the atmosphere? Why should WE pay the price?" I think it is a very important message to all of us. Indeed, in promoting economic development, can we do it without social justice, without equity, without fairness?

One of the environmental institutes has calculated the environmental impact of consumer products, using as a test case an average suburb in one of our cities in Canada. The premise is that taking into account the fruit and vegetables consumed in that area, the Fraser Valley near Vancouver BC, each household would need 1.7 acres of land if all these consumer goods were produced at home. But as we all know, those of us who live in Toronto, Montreal, Vancouver and other cities cannot own 1.7 acres of land each, so the conclusion is that we must borrow the land-shortfall from others. The solution: we borrow it from the Mexicans, the Costa Ricans, or others who produce the bananas, the oranges and the other produce and other consumer goods that we import in plenty because we have the money to buy them. And the other conclusion was this: if it is true that we need 1.7 acres of land for each household in Canada, what happens when all the other countries in the world reach our standards, those standards that we set for ourselves and the consumer society of waste and plenty? The answer is that we run out of global space. We then need another planet or two, and where do we find them?

Over-consumption is indeed a sad reality. For example, we used to think it was a mind-boggling statistic when North America reached a total of 250 million cars. Europe now produces its own tens of millions, now Asia is following suit. What happens when we have a billion cars spewing their gases around the world?

We must introduce equity into galloping consumerism. I ask: it is fairness when one of our big athletes, Michael Jordan, uses certain sports shoes, and for the privilege of using them, gets paid $25 or $30 million dollars a year? Who pays for that cost? It happens to be those workers out there, toiling away in a factory offshore at 10 cents an hour, so that there should be enough profit in these corporations which pay the $25 or $30 million bonuses to marquee athletes. Thus it is that the privilege of one top athlete here is underwritten by the toil of thousands of others who are underpaid over there. Is this sustainable development? Is this social justice? I think we would say not. I think we would say that in a fair and sustainable world, $30 million for one individual, especially in the circumstances, is an outrageous excess. Which brings me back to what was brought up before by Bob Costanza: when you apply ecological tariffs and ecological taxes, corporations will move where they're don't exist. However, consumers in the industrialized world are starting to have an increasing impact on market-place values, especially values of equity and fairness. Equity is going to become a huge incentive and a driving force in the market-place, because the world at large is a fair world, which tolerates injustice less and less and says: "No more! You cannot penalize the poor to make other people richer." So the source of production becomes a key element in a sustainable society and for our common future.

I realize we produce more and more luxury goods and cars and shoes and designer shirts by Tommy Hilfiger and others, because the market gurus tell us consumers demand it. Do they really? If the consumers when demanding those products knew they would have to pay for the proper social costs and the proper environmental costs, they would demand them far less. Because then our costs would reflect true equity and be far different from today's. What, for instance, would be the true and fair cost of a luxury car if we included the cost of subsidizing our roads to the tune of billions of dollars, let alone the cost of the collective pollution of these cars on the subsidized roads. Would we then, the consumers, ask for so many fast cars, so many polluting cars? No! We would start pressing for a different product, for a more affordable and sustainable product. I think a more realistic and equitable market-place would engender more sustainable industries and vice-versa. Take the example of catalytic converters. When legislation forced the automobile industry to install them, the industry fought against their introduction, complaining they would cost $400 each unit, and cause havoc to the industry. In actual fact, the cost per unit soon went down to some $40, and with them, cars became cleaner and greener.

One of my friends told me how his father used to take the train when he went skiing in the Gatineau Hills several years ago. This friend mentioned: "I would love to take the train myself but it is no longer there. I can't use my bicycle in the winter. It's too far to walk there. What do I do? Buses are few and far between, if any, so I have bought a car and I have to use it." What happens to the person who doesn't have a car? Well, he or she stays home. Is that a fair society? Did we consider these stay-at-homes when we abolished the train lines, or was it strictly and only a bottom-line decision? Indeed, is it an example of a sustainable and equitable society when we substitute roads for railway tracks, roads on which we pile more and more heavy trucks to carry our goods? We close the vicious circle by needing larger and larger subsidies for the same roads as collectively we pollute more and more. Instead of invoking the common good, we invoke the bottom-line and the profit imperative when lifting train tracks in favour of more roads and polluting vehicles. Is this a sign of a fair society, of a long-term society? I would say not.

It seems to me that the integration of environment and economy, based on the fundamental value of social justice, is intertwined with the central issue of short term vs. long term. Certainly, we could all produce many examples, many outstanding examples, of processes and actions which have bettered our quality of life in Canada and the United States, and elsewhere. Ken McCready, who spoke to us earlier, gave eloquent testimony on the many steps taken by the corporation he used to lead to make itself more environmentally-friendly, and more sustainable. He and his corporation deserve our unqualified praise. Laudable as such steps are, they are only part of the equation, for there happens to be a broader question. Should we not move from a polluting product—no matter how much cleaner than it previously was—toward longer-term and sustainable processes and products? In the case of energy, which Ken addressed, should we not take steps, beside making fossil-fuel production and products cleaner, to move towards renewable energy paths, such as solar, wind, and certain biomass energies? I realize what a challenge this is, for no doubt the Government of Alberta would invoke, justifiably, the essential need of the oil and gas industry as the basic and dominant industry from which Albertans derive all the socio-economic benefits they enjoy as citizens.

We are well aware that we, in Canada, are not meeting our commitments under the Climate Change Convention, which we had ratified with such determination. To meet the climate-change and energy challenge, we must build a consensus toward a long-term change in our socio-economic behaviour. We must start by earmarking gradually increasing tax-deductions and other fiscal incentives to favour the renewable energy sector. This will enable us to be progressively less dependent on finite fossil fuel reserves, which we can use more wisely, and in proportionately decreasing order as we gradually build up the sources and extent of the replacement energies of the future. In other words, do we wait for the near exhaustion of our fossil fuel reserves before we act decisively, or do we start planning and moving ahead now to institute the sustainable replacements of tomorrow? Moving ahead now to plan the future makes obvious sense. It would seem to me, and I say this privately knowing that my government has been overly timid that way, we should support the renewable energy sector much more decisively, by using the available economic instruments of tax relief and other fiscal incentives.

But unfortunately, we are a short-term society, electing governments every four years, planning from mandate to mandate, and seldom looking at the long term. It is neither wise nor forward-looking. We keep playing with the short-term, because the alternative is far less comfortable, and considerably harder to sell politically. So what we choose are minimal ways of tackling fundamental issues hoping they will sell. In climate change for instance, we strive to invent ways, and we use smart rhetoric, to mark time, and avoid the difficult long-term directions which our international commitments call for. Yet a rich industrialized society such as ours must show leadership, and the example to others who rely on us, that we are ready to change our attitudes, and the ways we do things. We cannot continue to shrug our shoulders, and claim this pretext or that for not moving forward with long-term ideas and policies.

There are skeptics who feel meaningful changes in societal behaviour are illusory. Yet there are visionary people, like Karl-Henrik Robert and Paul Hawken, who not only believe meaningful societal change can be achieved, but are proving, within the global marketplace, that it is possible to institute processes and products which respect nature fundamentally and are therefore sustainable. And that at the same time address the question of equity and justice, respect for the integrity of nature being an inherent system of justice. The aboriginal people of Canada, with whom I interact a lot, have convinced me that if we respect Mother Earth, then we live in an equitable balance one to the other, but if on the contrary we do harm to Mother Earth, we lessen one another's capacity to enjoy its bounty.

A few years ago I was involved, indirectly, in launching an environmental product, a banana. The banana is the staple food, as well as one of the economic motors for hundreds of millions of people around the world, in Africa, Asia and South America. This essential food is in increasing peril, because of two chronic diseases to the banana-tree, one attacking the root of the tree, and the other its leaves. Yet, the banana is a key export and hard-currency earner for many of the countries involved. So the large multinationals, which mass-produce and export bananas from these countries, turn increasingly to pesticides as the saviour. They keep throwing increasing doses of pesticides at the plants, to maintain their export drive. The struggling small planters who grow bananas for their own sustenance, or as suppliers to the multinationals, cannot afford the increasing cost of pesticides, and are shut out of the process. Besides, workers on the plantations are seriously affected by the increased pesticide use. In other words, both the people and the environment are losers, heavy losers. So the International Development Research Council of Canada funded a multi-year project in Honduras to discover a new, environmentally-sustainable, banana. Thus "Goldfinger" was born, a banana which does not require the use of pesticides. Its sister "Mona Lisa" has just been launched, and together they will not only continue to provide hundreds of millions of people with their staple food, but they will give economic independence, on a sustainable basis, to thousands of small planters, within a world-wide industry of 2.5 billion dollars. Thus environment and equity will benefit from visionary and meaningful change, in this case a massive change brought about by an innovative and effective project of modest means.

Just twenty-five years ago, a program called "Participaction", a program of mass-awareness and education, was launched—again with modest dollars—to inspire Canadians into fitness and health behaviours. At the time, the notion was widely publicized that a sixty-year-old Swede was fitter than the average Canadian half that age—and it was no doubt true. Today, twenty-five years after, Canadians have become extremely conscious of their health and nutrition. In every city, every small town or village, Canadians can be seen exercising, jogging, power-walking, cycling. It has truly been a revolution of mass-consciousness.

So people can change their ways, and businesses and industries can change their ways, and it is possible to bring about societal change of behaviour and attitudes. Not only is it possible, but we have no other choice, if we truly believe in a sustainable and equitable society.

I will close with the story of that old Mohawk woman who appeared before certain movers and shakers of our world. And she cautioned them: "When you've cut the last tree, when you have polluted the last stream, and killed the last fish, what will all the money in your banks do for you?" Indeed, our true wealth lies far beyond our banks and our market-place, in those natural resources and that bountiful biodiversity that same Mohawk woman would call Mother Earth. Those of us here, who are just as convinced as she was that our most precious wealth is our natural heritage, must continue to work ceaselessly, together, to persuade those around us that we must sustain it at all costs for the seven generations and beyond, to ensure our Common Future.

LAND USE AND SETTLEMENT ON THE CANADIAN GREAT PLAINS - EFFECT OF LAWS AND INTERNATIONAL AGREEMENTS ON LAND USE AND CONSERVATION

Greg Riemer

Saskatchewan Wetland Conservation Corporation, 202 - 2050 Cornwall Street S, Regina, Saskatchewan S4P 2K5

Abstract: Human activity has always been a part of the prairie landscape. Until European discovery, human populations lived in relative harmony with natural systems. With the settlement of the prairies, radical new views of land use impacted the grasslands. Implementation of concepts of private ownership, resource development, wealth generation, majority-rule and nation building resulted in the creation of the country we know as Canada and there is no question that the grasslands were changed forever by government policies. There is concern that the destruction of our native grassland ecosystem will continue. The author does not believe the destruction of the grasslands will continue as fundamental shifts have occurred in how governments can affect land use policies and programs. Data from the Canadian census indicate that in recent years in Saskatchewan the amount of farmland is declining.

A review of western Canadian settlement history in relation to government land use policy outlines a definite bias toward cultivation over forage-based agriculture. Western Canada's agricultural productive capability and exports are juxtaposed to Denmark, (a country with a similar agricultural climate) to provide a comparison in land use potentials. The recent major changes to national policy making options are outlined as are the opportunities that these policies avail for future conservation and stewardship programs on the prairies.

HISTORICAL PERSPECTIVE ON THE SETTLEMENT OF THE CANADIAN GREAT PLAINS

Canada as part of the British Empire of the 1800's viewed its right to develop the interior of the nation as it saw fit. This view was and still is commonly held throughout much of the world. The principal mechanism to effect change in any democracy is the law. The Oxford Dictionary Defines law as, "A body of enacted or customary rules recognized by a community as binding." In a Democracy, and for that matter probably in dictatorships as well, the law of the land becomes an instrument of Public Policy. It is through laws that governments appropriate funds and effect changes in the structure and function of society.

During the mid 1800's the government in Ottawa did not originally know what to do with the western portion of Canada then known as Rupert's Land. For the most part these "fur trading lands" were viewed as of little value. The first investigation into the potential of western Canada began with John Palliser who surveyed the Great Plains to assess their agricultural value from 1857 to 1860. His reports were published in 1859, 1860 and 1863. His travels through western Canada took place during a period of drought. Possibly as a result of this he determined that the limitations to agricultural development were very restrictive and he recommended against settling farmers on the Great Plains. This area of the Canadian Great Plains is still known as "Palliser's Triangle."

The American annexation of western Canada became a possibility beginning with the "54-40 or Bust" movement in the western states and ending for practical purposes with the Alaska Boundary Commission of 1899. Whether or not the threat was real is a case for speculation. At the time, however, the government in Ottawa took it seriously enough to reevaluate the settlement potential of Rupert's Land and to hire a new consultant to reassess the agricultural potential of western Canada. The man hired was John Macoun, who in 1872 made the first of four trips to the Great Plains. He concluded there were no impediments to cultivation in "Palliser's Triangle. His report coincided nicely with the construction of the Canadian Pacific Railway, which as any student of Canadian history knows was the principal ingredient in "the National Dream."

The disputed territories of western Canada which were a no man's land had to be converted to deeded land. The pattern of privately owned land was established in western Canada with the passage of a series of legislation tied to the construction of the railway and creation of the government's ability to grant homesteads. The original "homestead" was a free quarter section of land (160 acres) given to any settler provided that he or she live on it and cultivate a certain portion of it. The railway was completed in 1885 but the massive influx of settlers did not materialize in spite of hard times and starvation in Europe and massive immigration to the USA. The government's response was the Crow's Nest Pass Act which was passed on September 6, 1897. Twelve years after the completion of the rail line the federal government realized that being more than a thousand miles from export position placed grain farming on the Canadian prairies at such a disadvantage that subsidizing the export of grain was the essential element required. Subsidized freight of grain began the land rush. The "Crow" as it is affectionately referred to by grain farmers has paid a large portion of the freight bill on exported grain for almost 100 years. Land Tenure became the principal tool of Nation building. There was no question about who owned western Canada.

The key to prosperity was cultivation and wheat production. The provisions in both federal and later provincial legislation ensured that if land was allowed to "go wild" the homestead rights were revoked or land taxes increased. This attempted to ensure that the new settlers would not allow their land to revert to pasture. Grain production continued to receive increasing government support until the early 1990s while the livestock sector was essentially unsubsidized. Through this whole period of settlement and development it is this author's opinion that the government maintained the view that the only real use for the Great Plains was the production of grains for export. This view is reflected in the land use of the prairies.

Figure 1 tracks the number of farms in Saskatchewan from 1911 to 1996 and the average size of those farms. The number of farms increased steadily except for the early depression years and peaked in 1936. Since that time the number of farms has decreased steadily. The size of farms appeared to reach a plateau in the 1920's and 1930's limited by the technology and resources available to work the land. However, following the depression the size of the average farm increased in what appears to be a linear relationship right up to the present day.

Figure 2 tracks the amounts of both total land in farms and total amount of cultivated land in the province of Saskatchewan. The figure shows that a relatively rapid increase in both amounts occurred prior to the 1930's. During the 1930's the growth of total land in farms slowed and did not resume until after the war ended. At this time the amount of land cultivated increased

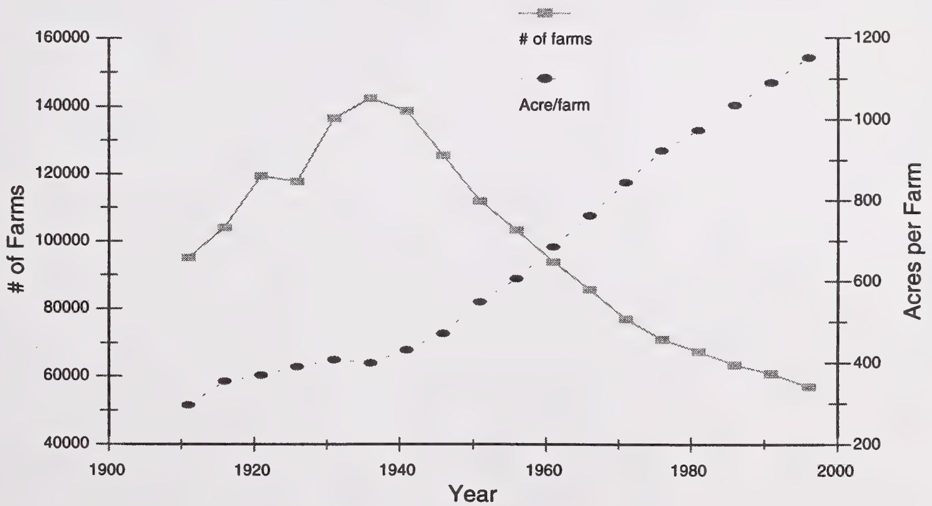

Figure 1. The number of farms and farm size in Saskatchewan. Saskatchewan Department of Agriculture and Food (SDAF), Statistics 1996.

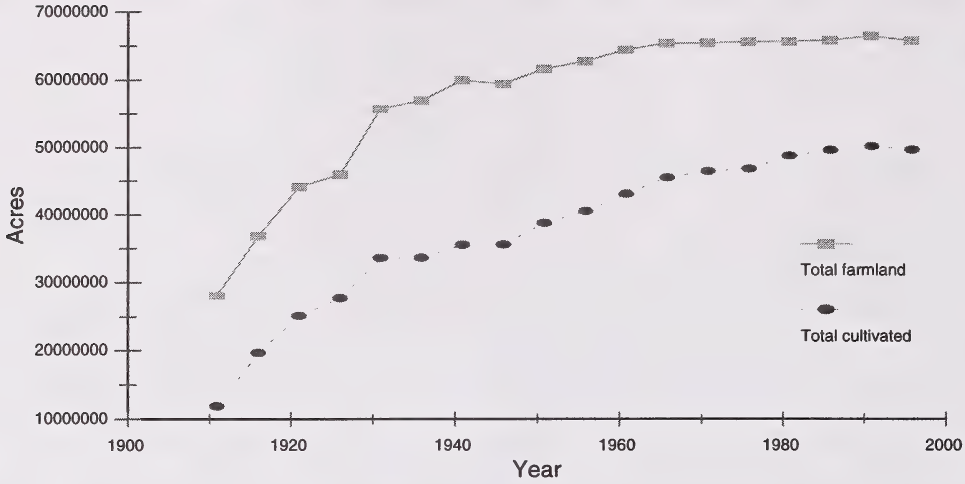

Figure 2. Total acres (upper line) and acres cultivated (lower line) in Saskatchewan over time. SDAF Statistics 1996.

faster than the total amount of farmland. This situation is better demonstrated in Figure 3 which tracks the percentage of farmland in Saskatchewan that is cultivated.

While Figure 2 showed that the amount of farmland in Saskatchewan was steadily increasing, Figure 3 demonstrated that except for a brief period during the depression and the war years the percentage of farmland that was cultivated increased steadily until the 1980's. From a waterfowl management perspective the jump from 70% cultivated in the early 1970's to more than 75% ten years later was a significant factor (combined of course with the drought of the 1980's) in the decline of waterfowl numbers.

The end result of more than one hundred years of Canada's nationally driven cultivation-based settlement policy is, as would be expected, one of the most rapidly altered landscapes on the planet. In Saskatchewan's case 65 million acres of land have been brought into agriculture with 50 million acres or roughly 75% of it cultivated.

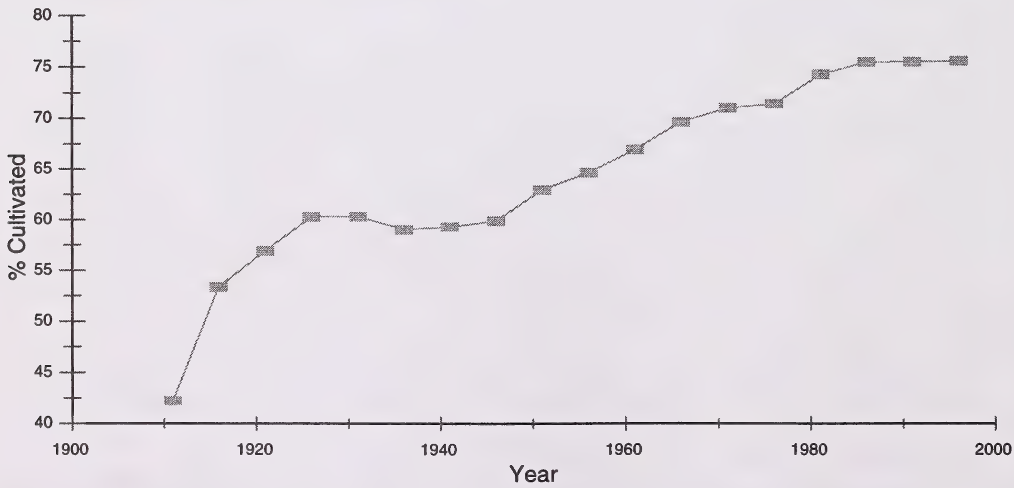

Figure 3. The Percentage of total Saskatchewan farmland cultivated over time. SDAF Statistics 1996.

THE PARADIGM SHIFT

A paradigm shift occurs in the formulation of national policies when international priorities outweigh a single nation's priorities. One of the first examples of this was in waterfowl management more than 50 years ago with the signing of the International Migratory Bird Treaty. This ended commercial hunting and regulated harvests. Subsequently the North American Waterfowl Management Plan (NAWMP) shared costs of restoring populations of waterfowl. In spite of this example, governments as a general rule seem better able to deal with priorities of economic development and trade than with environmental issues. Of particular relevance here are multilateral agreements such as the General Agreement on Tariff and Trade (GATT) Sub Agreement on Agriculture in 1993 and bilateral agreements like the initial North American Free Trade Agreement (NAFTA) and the Kyoto agreement on carbon emissions in 1998.

I believe that national governments have demonstrated that they are more likely to make real change when that change is forced on them by international pressures as opposed to internal pressures. Governments reflect the wishes of the majority of people; people desire stability and the status quo.

In terms of land use policy reform the GATT: Agriculture Agreement has had an unprecedented effect. Never before had internal agricultural policies been directed by international agreements. The GATT has worked well in the manufacturing sectors and to date has shown every indication that it will work well in agriculture. Essentially, signatory nations to this agreement agreed that regulated government involvement in agricultural production would result in increased world trade and competitiveness. Signatory nations agreed to end trade-distorting subsidies. In a nutshell the GATT forces nations to stop subsidizing the production and export of food and to stop penalizing imports. This means that nations that have a natural advantage producing a particular food product will not have to complete with unfairly subsidized products.

The effect of this on our highly subsidized export grain sector and the land base that it utilizes cannot be overstated. Within a few years of signing these trade agreements agriculture in western Canada is almost completely unsubsidized. Some of the subsidies that were removed include The Western Grain Transportation Act (which replaced the "Crow" and was determined to be a subsidy by GATT), The Gross Revenue Insurance Program (GRIP) , the old shipment quota system, port averaging (which in simplistic terms used Saskatchewan and Alberta farm revenues to subsidize the shipment of grain produced on the eastern Great Plains through the St. Lawrence Seaway).

The signing of these agreements gave government, which has traditionally been comfortable with the status quo, a real reason to change the way it did business. The effect of this basic change in policy formation has been real. Figure 2 looked at the amount of land in Saskatchewan farms from the turn of the century on. The scale of this figure has been shortened in Figure 4 to better show the changes in the amount of farmland over the last 30 years.

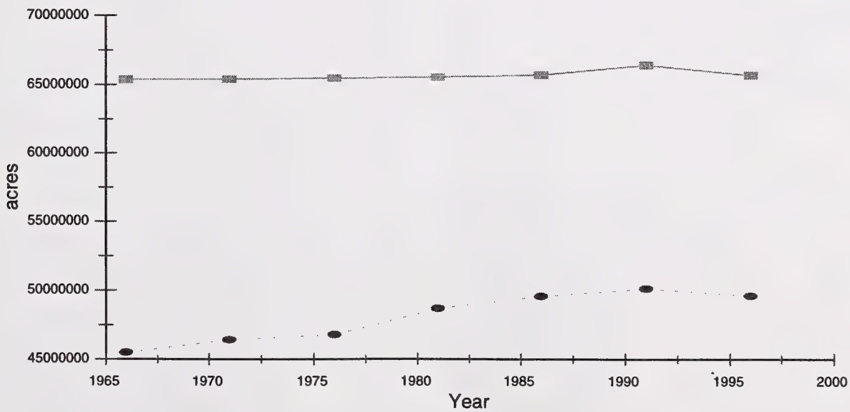

Figure 4. The total amount (upper line) and amount of cultivated farmland (lower line) in Saskatchewan over the last 30 years. SDAF Statistics 1996.

The effect of international trade policies on land use in Saskatchewan can be surmised from Figure 4. From 1991 to 1996 750,000 acres dropped out of the total amount of farmland in Saskatchewan. This was paralleled by a 500,000 acre drop in the amount of cultivated land. Never before in the history of the settlement of Saskatchewan has such a thing happened. The closest example to this occurred at the end of World War 2 when the total amount of farmland in Saskatchewan declined but the amount of cultivated land increased (Figure 2). Whether or not this trend continues is open to speculation but one can be safe in saying that the pattern of landscape change in Saskatchewan is changing. How much it will change is anyone's guess.

A CASE STUDY: DENMARK, THE HOG CAPITAL OF THE WORLD

Denmark is a small, relatively flat coastal country on a northern latitude and is almost completely surrounded by ocean. By western Canadian standards every farm in Denmark is within trucking distance of a seaport. Denmark is also a very mature agricultural nation with well developed infrastructure, production and marketing cooperatives and a Japanese like work ethic. Denmark stresses value adding to its primary production. Historically it is a producer of small grains and has expanded its hog production to almost completely utilize its grain production capability.

Five million people live in this 43,000 km^2 country. This translates to 116 people per km^2, a densely populated country by western Canadian standards. Denmark slaughters 20 million hogs a year, 80% of which (almost 700,000 tonnes) are exported as pork. This export is worth 4.5 billion DK per year to the Danish economy. Twenty million hogs is equal to 2% of world production but 25% of world export trade in hogs. If Denmark alone was to supply a 1% increase in the world demand for pork, its production would have to increase by eight million hogs.

Danish grain production is almost completely consumed domestically. Based on its current production capability its industry would not be able to supply much more of the basic requirements for a dramatic increase in hog production. Grain is produced on a land base a quarter of the size of Saskatchewan's cultivated land base. While average wheat yield in Denmark is high at 116 bushels per acre, total grain production was only 9,000,000 tonnes in 1996. That year the Danes had a carry-over of 1,774,000 tonnes and exported only 1,890,000 tonnes (principally to the EU). This example of exporting the carry-over appears to be a trend in recent years and may reflect a desire on the part of the Danish hog industry not to rely on carry over as a sure supply of feed.

In 1997 Canada produced 395,000 tonnes of pork and is a minor player in world markets. With increasing world demand for pork the potential seems limitless. To completely utilize the total grain production of Saskatchewan (roughly 30 million metric tonnes) would require an increase of only 8.3% in world demand for pork. It is safe to say that the hog industry is here to stay and in all likelihood to expand.

THE QUESTION

The main point of this comparison is to ask the question, "If a mature nation like Denmark, which is in an excellent location for exporting raw commodities, exports only a minimal amount of its grain production, is the continued export of grain from the Canadian prairies a given?" If not, what are our options? If we cannot economically maintain grain exports, can we expand the feeding sector fast enough or even maintain the grain industry? As conservationists, do we want the prairies to be like Denmark? I sincerely wish that I had the answers to all these questions. The one thing that I am sure of is that the options for land use change are not restricted to the Denmark model.

Our options for land use also include shifting land to forage-based agriculture. Carbon emissions will become a driver of government policy as we realize what we committed ourselves to at Kyoto. With the potential to fix vast amounts of carbon per acre there may soon be federal government programs to assist landowners with seeding land back to grass. Saskatchewan already has a large base of rangeland from which an expansion of the grazing-based livestock industry is more than possible. The cow-calf industry is an extensive use of the land that produces high quality food at a very low environmental cost. Seeding marginal cropland back to grass would expand the beef industry, provide a buffer for our native rangelands, provide environmental benefits in terms of soil, water and air quality, and increase the amount of wildlife habitat. It remains my choice as the best land use change option.

The land base in agricultural Saskatchewan is privately owned or controlled. As conservation agencies we cannot purchase enough land to have any significant effect. Stewardship projects are most cost effective and impact the most land. Our efforts must be aimed at working with the landowner; only then do we become stewards. In our dealings with governments and landowners we cannot be constantly negative! Things will change in spite of us. Only in real partnerships are we effective. It is up to us to determine what we do and whom we work with.

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WHAT'S WRONG WITH US? A SELF-CRITICAL LOOK AT CONSERVATIONISTS

Monte Hummel

World Wildlife Fund Canada, 504 - 90 Eglinton Avenue E, Toronto, Ontario M4P 3A4

Abstract: Conservationists are at our worst when we come across as formally educated only (having allowed our schooling to interfere with our education); out of touch with local people (arrogant); urban (condominium environmentalists); unsympathetic to any form of profit (naïve); exclusively protectionist (save Bambi); lacking in practical experience (cloistered); superior (paternalistic); doctrinaire (intolerant); never satisfied (terminally whiny); trying to run the world from a computer terminal (nintendo-science nerds); lacking rigorous homework (innumerate), and generally believing that the federal government must (and can) solve all our problems.

Conservationists are at our best when we come across as passionate but sensible (inspiring); drawing support from local people (representative); purveyors of accurate information (well informed); people with dirty boots (practical); good listeners (still learning); respectful (decent); in this for the long run (determined); ready to work with a full range of players (trusting); ready to experiment with new ways to solve old problems (creative); people who also consume resources and go to the bathroom (human); not the only ones who care (righteous, but not self-righteous); and believing that the provinces could (and have) done one thing right, ever.

THE PRIVATE/PUBLIC LAND CONFLICT

Cliff Wallis
Past-President, Alberta Wilderness Association

Abstract: Millions of people who are the rightful owners of public lands are being shut out of the use of and decision-making for their lands. Provincial governments have largely failed in their duty to represent the broad public interest. They increasingly pander to the economic interests of a small rural elite to the detriment of the natural diversity of the prairie and parkland region. For minimal fees, lessees have effectively gained exclusive rights to public lands, thereby stifling alternative economic activities and marginalizing biodiversity conservation.

The government has spent millions of taxpayer dollars acquiring private lands for parks, wildlife areas and recreation when there are thousands of square miles of public lands in the settled parts of the prairies that should be freely available for the protection of biodiversity, recreation and the wise use of all people.

Private lands offer some hope for biodiversity conservation but, generally, the few remaining large blocks of prairie wildlands are on publicly owned land. The history of private land ownership in prairie and other environments around the world is that they are managed on a short-term economic horizon. This has resulted in habitat destruction on a grand scale and led to numerous wildlife conflicts. Public lands have the greatest opportunities for long-term biodiversity and wildland protection in the Canadian prairies. Governments need to redefine their goals for public lands with an emphasis on environmental protection. They should reacquire critical prairie habitats back into public ownership or secure long-term conservation agreements for the maintenance and restoration of prairie ecosystems.

Public lands represent one of the greatest opportunities for long-term biodiversity and wildland protection in the Canadian prairies. The millions of rightful owners of public lands are largely being shut out of the use of and decision-making for their lands. In Alberta, government has shifted from representing this broad public interest to pandering to a small rural elite. Governments have spent millions of taxpayer dollars acquiring private lands for parks, wildlife and recreation when there are thousands of square miles of public lands in the prairie and parkland regions that should be freely available for the protection of biodiversity, low-impact recreation and wise use.

Unfortunately, governments have effectively privatized these lands through outright sale or by conferring exclusive rights on grazing lessees. One million acres of Tax Recovery Public Land was sold to municipalities in Alberta over the last ten years and another 300,000 acres could go soon. The public was never consulted on the sale of their land. Despite recommendations from a 1987 task force and a Policy for Environmental Protection that states that all Albertans shall have the opportunity to have input on decisions affecting their environment, the government has implemented a policy which allows these public lands to be sold to the municipalities. Many of these lands include key wildlife habitat and other environmentally significant areas of national and provincial importance.

The current sales in Alberta violate the report of a 1987 MLA task force that recommended no further sales of public lands until a comprehensive policy was developed. The task force actually recommended acquiring more land into public ownership to help protect critical wildlife habitat. Legally, these Tax Recovery Lands are no different from other public lands. The southern regional integrated resource plan states: "tax recovery lands that possess multiple resource values should be acquired." The sale of these environmentally significant lands flies in the face of this recommendation.

Sale into private ownership has generally been the death knell for large native prairie areas. With a few notable exceptions, the largest, least fragmented, most diverse biological areas and stunning prairie landscapes lie on public land. Due to economics and history, most private lands in the prairies have succumbed to the plough or have been fragmented into small parcels that have little potential for amalgamation into large protected blocks of prairie wildland. While there are new tools such as conservation easement legislation that weren't available several decades ago, we have too little experience to relinquish control of the few remaining public lands to an uncertain future in private hands. In any case, the public land sales in Alberta are being made without any caveats or conditions that would guarantee their future as native, well-managed grasslands.

Private landholders and, with government complicity, grazing lessees have increasingly restricted access to prairie lands. In some cases, this has made it impossible for government biologists and consultants to access and conduct studies on prairie habitats and wildlife, even when these lands are owned by the public!

The history of Alberta government commitment to the recommendations on public lands from its own appointed bodies has been dismal:

1. Despite an outpouring of public input, the 1987 Grazing Lease Conversion Task Force report was largely ignored because of pressure from cattlemen (Grazing Lease Conversion Task Force 1987). The task force recommended:

   - foot access be allowed at all times
   - key or critical wildlife habitat should be retained in public ownership or purchased where deeded
   - a new grazing land management policy should be developed
   - any change of public land use should occur as a result of a public planning process

None of these recommendations was implemented. Access is still at the discretion of the lessee. Conservation groups wanting to educate their members and learn about the value of critical wildlife areas have been refused access to public lands. Despite repeated assurances from the Premier, Alberta still does not have a public lands policy.

2. An August, 1990 recommendation made to the Minister of Alberta Forestry, Lands and Wildlife on public access has similarly not been implemented. This report recommended that the Public Lands Act be amended so that the public would be assured a right of reasonable access to public land under grazing lease disposition (Fish and Wildlife Advisory Committee on Access/Trespass 1990).

The resulting lack of action on recommendations made to government by its own appointed bodies and the recent sales of public lands have increasingly frustrated Alberta conservation and recreation organizations. Government is promoting a conflict model for resolving these issues. While the cattle industry will control the agenda over the short-term, the long-term outlook is unclear. Ultimately, the increasing polarization and the sheer weight of numbers of urban residents will likely overwhelm the relatively small ranching community.

At least if the lands stay in public ownership we will still have some native prairie wildlands to fight over in 50 years. However, the outlook for prairie conservation will not necessarily be positive if the principal conflict comes from off-highway vehicle users and other recreationists who have little interest in sustainable land use. A better model for resolving these issues would be to have the cattle industry cooperate with the environmental community to promote a Public Land Policy and legislation that would recognize:

1. a broader societal interest in conserving and using public lands;
2. the right of the public to have reasonable access to public lands;
3. the role of public lands and the types of management that would protect ecosystems; and
4. the role of grazing in public land conservation.

Governments continue to create the false impression that agriculture is the only important economic activity on public lands. To the contrary, in Alberta there are only 7800 agricultural dispositions on public lands and over 35,000 other dispositions. In addition there are tens of thousands of recreational user days spent on public lands for which there is no accounting. Why then is agricultural use deemed to be the primary use of public land? An October 1996 report by Alberta Environmental Protection showed that legally designated protected areas on public lands contributed, on a per hectare basis, as well as or better than the agriculture industry in terms of GDP and person years employment. It is clearly time for government to take leadership on this issue and place biodiversity conservation as a priority on public lands. Excellent range management does not necessarily mean great ecosystem management. It is in the cattle industry's own self-interest and the interest of prairie conservation to work cooperatively with the environmental community to come up with defensible solutions to public lands conflicts. With the participation of government and non-government organizations we could turn ranchers from great range managers into good ecosystem managers.

We cannot afford to have the fate of the public land base in the Grassland and Parkland regions to be decided by a single focus sector. While they have an important role to play in managing and conserving public lands, the ranching community should not have exclusive rights over these areas. This conflict will continue to simmer and may boil over. The public will apply increasing pressure until this situation is resolved. The concept of dominant public use that gives priority to recreation, wildlife and watershed uses will be strongly advanced by the conservation community. As we lose more habitats and more species become threatened, this will likely result in more regulation of private land. To guard against this, it would appear to be in every private landowner's interest to ensure that there are sizeable blocks of native grasslands on public land that protect healthy populations of prairie species.

In their 1997-2000 business plan, Alberta Environmental Protection says it will develop comprehensive Integrated Natural Resource Policies and update policies and legislation for public land. Alberta Agriculture Food and Rural Development notes that the Prairie Conservation Action Plan calls for adopting land use practices and protective strategies that support the ecosystem for the entire land not just for selected sites. This will be impossible to achieve unless there is an overall Public Lands Policy that recognizes the protection of the ecosystem as paramount to deriving all the economic benefits out of these public lands. Further sale into private ownership or effective privatization by conferring exclusive rights on lessees will only thwart these efforts. Retention of large prairie land bases in public ownership were some of the most visionary actions that previous provincial governments took. There is too much at stake to lose these important prairie lands to private (or *de facto* private) ownership where the public will have no say in their future, where there may be no public access, and where productive prairie wildlife areas will be turned into non-native, impoverished monocultures.

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AGRICULTURE AND WILDLIFE - WORKING TOGETHER

Lorne Scott

Minister of Environment and Resource Management, Box 995, Indian Head, Saskatchewan S0G 2K0

Abstract: Significant progress has been made working with endangered species since the first Prairie Conservation and Endangered Species Conference in Edmonton. Much work remains to be done. One of the most positive aspects of our work is the way agricultural and environmental interests have drawn together. This has produced cooperative efforts like Operation Burrowing Owl, conservation easements legislation and programs from Saskatchewan Wetlands Conservation Corporation which assist landowners who wish to plant grass. The Prairie Conservation Action Plan, which was released today, is the type of cooperative planning and program needed to maintain biodiversity on the prairie. It shows great promise because it was developed by a coalition which included the very active participation of the Saskatchewan Stock Growers Association. This plan focuses on maintaining the native prairie, its biological diversity and on promoting its sustainable use.

It is a pleasure to be here at another Prairie Conservation and Endangered Species Conference.

As always we have many issues and ideas to discuss and, I'm pleased to note, we have made significant progress since this series of conferences first began in Edmonton in 1986. Endangered species recovery teams have been established for the vertebrate species listed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada). The federal-provincial Recovery of Nationally Endangered Wildlife (or RENEW) Committee is now beginning to look at other taxonomic groups such as plants and invertebrates. Here in Saskatchewan amendments to *The Wildlife Act* have broadened the definition of wildlife to include all wild plant and animal species.

However, I am most pleased by the way environmental and agricultural groups have drawn together on many key issues. Saskatchewan's farmers have come through a difficult period. Low prices and changes to agricultural policies and programs such as GRIP, the quota system and the Crow Rate are causing major changes in the agricultural industry. While these changes have been difficult, they have also removed subsidies which encouraged cultivation of marginal lands. The changes have made more environmentally friendly practices, such as grazing, more competitive.

Conservation initiatives such as *The Conservation Easement Act* can make adjusting to these changes easier for landowners. Saskatchewan Wetland Conservation Corporation has been assisting farmers to put land back into grass by subsidizing the seed—a simple effective program which has been over-subscribed each year. This year with the help of Ducks Unlimited, the effort will be doubled and I expect to see it continue to grow. The farmer manages the grass as he wishes, no regulation, no one looking over his shoulder. But as you know, grassland species do better with more grass cover on the land, so wildlife and agriculture benefit.

In January of this year SERM announced the signing of our first Conservation Easements under Saskatchewan's new *Conservation Easements Act*. Conservation Easements allow a landowner to provide long-term protection to valuable habitat, while keeping control over the land and retaining existing uses. The land owner benefits by obtaining an income tax credit or a direct payment from a conservation organization. Therefore, he or she no longer has to carry the whole cost of protecting habitat.

Habitat along rivers, creeks, lakes and other water bodies is a very productive part of the prairie landscape. Its importance to wildlife, fish and the protection of water quality is undisputed. Saskatchewan Environment and Resource Management and the Saskatchewan Wetland Conservation Corporation have worked with nearby landowners and grazing co-ops to protect this valuable habitat from detrimental over use. These protection efforts are undertaken with the support and cooperation of landowners, which is essential for long-term conservation success.

Many of you are familiar with Operation Burrowing Owl's success in securing the voluntary cooperation of more than 400 farmers to maintain nesting areas for this endangered species. Perhaps the best example of their commitment to this program is that many landowners continue to protect the habitat, even when the owls no longer return to their land. Unfortunately, it also shows that loss of nesting areas is not the only problem affecting Burrowing Owls. Despite continuing population decline, the program is successful in protecting nesting areas.

In 1997 Saskatchewan enacted amendments to *The Wildlife Act* to protect species at risk, including plants and invertebrates. Our intention in developing these amendments was to have a legislative tool to protect endangered species while working cooperatively with the land owners who support these species.

Cooperation is the Saskatchewan way. Our previous experience shows cooperative approaches are effective and provide lasting benefit. Government and others, working with individual land owners and agricultural groups, can work together to find the best way to protect species at risk over the long term.

As called for under the new endangered species legislation, a scientific working group, which includes provincial experts on fish, invertebrates, plants, reptiles and other species, is currently reviewing the status of various species. Species currently listed by COSEWIC are being reviewed as the first priority. The working group will then move on to candidate species identified by the Saskatchewan Conservation Data Centre and other sources. I expect the first species to be listed under the legislation this spring.

Yesterday at this conference, Premier Romanow announced completion of a new Prairie Conservation Action Plan for Saskatchewan. This is exactly the type of cooperative initiative we need to make conservation progress on the prairie. One of the key reasons I like it is because the Saskatchewan Stock Growers Association has been a major force in developing the plan and is proposing to lead the implementation team. When a major agricultural group is the lead agency in a major new conservation initiative, you are clearly finding the common ground which leads to sustainable conservation initiatives.

The new PCAP includes five goals for Saskatchewan:

- First, to sustain a healthy, native prairie grazing resource.
- Second, to conserve the remaining native prairie resource.
- Third, to maintain Saskatchewan's native prairie biological diversity.
- Fourth, to promote the sustainable use of native prairie to enhance the quality of life.
- And fifth, to promote education and develop communication programs regarding the conservation and sustainable use of native prairie.

Objectives have been set, agencies have agreed to be involved in implementation and time lines have been established to achieve the goals of PCAP. The plan identifies specific problems, such as the negative affect of current property tax assessment policies on the maintenance of prairie. The plan also identifies actions to determine the real impacts and ways to correct them.

The plan also endorses major conservation initiatives, including the Representative Areas Network, which the Premier also mentioned yesterday. This broad-based support is essential because the Representative Areas Network, in the prairie and parkland, will need to include significant areas that allow for compatible uses, especially grazing. There are no large areas left in these ecozones which are not being used by people. Representative areas can only be negotiated with the current users' willing participation. As well, ecologists now understand that our grasslands evolved with grazing and depend on periodic grazing to remain healthy. With the type of cooperation shown in drafting PCAP we will find ways to protect large representative areas of prairie for grazing and ecological representation, while restricting ecologically damaging activities.

SERM and other wildlife agencies like Ducks Unlimited are also learning that grazing or haying can be valuable management activities on lands managed for wildlife. For example, the lands purchased to mitigate wildlife habitat losses to Rafferty Dam are managed using a planned grazing system. Local people are receiving economic benefits and the grazing maintains the quality of the habitat over the long term.

I wish to compliment many people in the agricultural and wildlife communities. People like Miles Anderson, President of the Saskatchewan Stock Growers Association, and many others have helped in drafting the Prairie Conservation Action Plan. As well, I want to recognize the many farmers like Grant and Sheila Fahlman who have protected habitat, through Operation Burrowing Owl easements and on their own, and the biologists and agrologists who work with them.

I have focused on only a few of the many initiatives which Saskatchewan has recently undertaken to achieve our objectives of not only sustaining but rebuilding our threatened prairie habitat and wildlife species. I am the first to admit however that there are many areas where more needs to and can be done. While the challenges ahead are great I am convinced that, working together with the province's landowners, who are the real stewards of this province, we can achieve our goals and a sustainable economy.

Through a lack of understanding and sometimes poor agricultural practices, we have made the prairies one of the most threatened ecosystems in the country. As understanding grows of our place in, and impact on, the natural systems that sustain us all, we have developed greater concern and directed more effort to preserve and sustain those systems.

To address these and other concerns we all need to work towards common goals and objectives. Working cooperatively works. I believe that and you believe it, otherwise we wouldn't be here. This conference and Saskatchewan's Prairie Conservation Action Plan are proof that government, farmers and ranchers and conservation groups can work together to protect rare and endangered species and places. I sincerely appreciate the interest and work that so many people have committed to this important cause in Saskatchewan.

PROPOSED ENDANGERED SPECIES LEGISLATION

H. Loney Dickson
Canadian Wildlife Service, Environment Canada, 2nd Floor, 4999- 98 Avenue, Edmonton, Alberta T6B 2X3

On behalf of the associate director general for the Canadian Wildlife Service, Environment Canada, Steve Curtis, I want to thank you all for the opportunity to take part in this the 5th Prairie Conservation and Endangered Species Conference. I think it is worth noting the range of interest represented at this conference this weekend….representatives from industry, environmental, wildlife, agriculture and aboriginal communities, as well as provincial and federal partners.

Today I would like to present you with an update on the status of The National Accord for the Protection of Species at Risk in Canada. The National Accord is a very important undertaking which represents the umbrella under which the many pieces of federal, provincial, territorial and non-government programs link together in a truly national mosaic. I also want to let you know some of the results from the national workshop on the Accord, held on February 18, 1997 in Ottawa and attended by over 100 participants from various stakeholder groups and governments. Some of those participants are here today. The Ottawa workshop represented the first step of many steps which, when completed, will provide Canada with a truly effective national approach for protecting species at risk. But first I want to spend a few minutes talking about a couple of subjects of interest to us all.

As you all know, on October 31, 1996, Minister Marchi introduced Bill C-65,the draft Bill for a Canadian Endangered Species Protection Act (CESPA). That bill was considered after first reading by The Standing Committee on the Environment and Sustainable Development. This Committee recommended a number of amendments to the Bill. But, as you are aware, the Bill died on the Order Paper when the June 1997 federal election was called. I think it is fair to say that not everyone has been an enthusiastic supporter of Bill C-65, and many have underscored that it departed in significant ways from the National Accord and underlying Framework.

At the Wildlife Ministers' Council of Canada meeting in October of 1997 in St. John's, ministers agreed that it was necessary to return to the first principles embodied in the National Accord and instructed officials to develop a comprehensive Workplan for implementing that Accord, a Workplan complete with commitments and deadlines. This of course includes federal legislation. Ministers emphasized in their final communique in St John's and in the ensuing press conference that their legislative tools should respect the authority that each level of government enjoys and should be mutually reinforcing and complementary.

So what does that mean? It means that the shape and timing of new federal legislation will be determined as we further develop the implementation plan for putting in place the entire Accord. When will a proposed Canadian Endangered Species Protection Bill be tabled in parliament? As soon as possible, but honestly, I don't know. But what I do know is that there will be ample opportunity for all interested parties to help us shape and hopefully come to some agreement on what the federal legislation should contain.

We have heard from many of you, and others not here today, that there are outstanding concerns (for and against) about the provisions dealing with: cross-boundary species, application of CESPA in the Territories, civil suits and the operation of COSEWIC (the Committee On The Status Of Endangered Wildlife In Canada) and the proposed Canadian Endangered Species Conservation Council (CESCC). There may be others but these are the top 4.

There is also one more important message that we have heard loud and clear from everyone: that we cannot protect species at risk by simply legislating it to be so. We must simultaneously develop programs and policies that support and reinforce stewardship of our lands, the conservation of species and, more specifically, the protection of species at risk in a voluntary way. I am extremely encouraged by the many initiatives that are currently underway to do just that.

In March 1997, Environment Canada co-sponsored a workshop with the National Agriculture Environment Committee on "Incentives and other Mechanisms to Contribute to the Environmental Common Good." As a follow-up to the workshop, we continue to participate with interested stakeholders from the agricultural, mining, pulp and paper and the environmental community on an ad hoc forum on stewardship. The World Wildlife Fund, as a continuation of that work, is currently conducting a survey on the types of incentives that are perceived as most effective by various stakeholders. Over the last ten months, we have been working closely with colleagues in Industry Canada and Natural Resources Canada to explore non-regulatory instruments for industry that would benefit wildlife and wildlife habitat. These are all extremely important elements of a collaborative effort.

At the workshop in Ottawa on the Accord, participants reiterated the need to ensure that stewardship programs be an integral part of any national species recovery program. That voluntary land and species stewardship programs needed to be identified for industry, landowners and others to implement on a voluntary basis to protect habitat, species and ecosystems before the "stick" is brought out. As Monty Hummel of World Wildlife Fund indicated, what we need is a foam stick, where the foam represents the voluntary efforts that can be undertaken for species at risk conservation (be they tied to land management practices, voluntary environmental assessment processes of industry, or voluntary conservation initiatives through cooperative agreements), some of which we saw announced yesterday. Only after these programs did not acquire the desired results, would the legislative stick come into play. Hence a program with a voluntary (good faith) approach, followed by mutually agreed to activities and ending, when necessary, with mandatory actions. This is the type of considerations and further discussions that are needed over the next while to move species at risk conservation efforts forward.

At the workshop, participants were provided with a draft document that summarizes the collective interpretation of the Accord, and with a snapshot of where jurisdictions currently are in their respective efforts at protecting species at risk, a stock taking if you will, which will enable identification of gaps and serve as a basis for the Workplan. Other issues discussed at the workshop and for which written material was provided included the Stewardship Options Survey, the roles and responsibilities of COSEWIC and the CESCC, and a monitoring program on the general status of wild species. From those and other discussions participants also identified that compensation, socio-economic considerations and education programs were issues that needed to be addressed as we develop and move the Accord forward.

Copies of the documents mentioned above are available from the author.

CONSERVATION, SOCIO-ECONOMICS AND ETHICS

KEYNOTE LECTURE: ECONOMIC GROWTH, CONSERVATION, AND SUSTAINABILITY: FOOT-PRINTS TO AN ETHICAL DILEMMA

William Rees

Community and Regional Planning, 6333 Memorial Road, University of British Columbia, Vancouver, British Columbia V6T 1Z2

Abstract: Conventional economic wisdom argues that poverty is the principal cause of ecological degradation and, therefore, that the road to sustainability is paved with sheer economic growth. In theory, rising incomes should eliminate human economic misery and provide the means to clean up and protect 'the environment.' By contrast, I argue that mainstream money-based arguments misrepresent the biophysical dimensions of human ecological reality. 'Ecological footprint analysis' recognizes that the physical flows of energy and material through the economy are the main drivers of global ecological change and shows that these flows are mainly associated with consumption in high-income countries. The data indicate that the wealthy 25% of the human population have already appropriated the entire long-term carrying capacity of the Earth in several important dimensions. Indeed, the residents of wealthy North American and European countries typically consume three or four times their 'fair share' of the biophysical output of the ecosphere. While conventional economics ignores moral questions, the economic growth ethic actually presents us with a double-barreled moral dilemma. On the one hand, further growth in human populations and human-made capital poses a fundamental and unavoidable conflict with biodiversity conservation and ultimately with ecological sustainability (what humans appropriate for themselves is unavailable to other species). On the other hand, without growth we must face the growing income gap directly. If we cannot grow our way out of poverty, the already wealthy may have to give up living so high on the hog in order that others may live at all.

IS THE RURAL POPULATION OF SASKATCHEWAN A SUSTAINABLE SPECIES?

Christopher Lind

St. Andrew's College, 1121 College Drive, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W3

Abstract: Like other endangered species, the rural human population in Saskatchewan is threatened by a combination of subtle, complex, and powerful forces. Together, these forces are known as globalization. Contrary to the currently dominant modernization analysis, which endorses depopulation as an adaptive strategy, a globalization analysis calls for organized resistance in order to restore the habitat of rural community. In this paper, it is argued that Saskatchewan's rural population is under threat because its numbers are declining and its habitat is eroding. If this pattern is not reversed, this population will become endangered.

INTRODUCTION

Like other endangered species, the rural human population in Saskatchewan is threatened by a combination of subtle, complex and powerful forces. Together, these forces are known as globalization. Contrary to the currently dominant modernization analysis which endorses depopulation as an adaptive strategy, a globalization analysis calls for organized resistance in order to restore the habitat of rural community.

In describing rural human populations as an endangered species, I am not trying to make a technical biological argument. For example, I am not trying to get the population of Vanguard, Saskatchewan listed by the Committee on the Status of Endangered Wildlife in Canada. (Though that would be an intriguing political strategy!) Rather, I am picking up on the use of biological and evolutionary metaphors by the defenders of rural structural adjustment, to ask the following questions: If we were to think of Saskatchewan's rural human population as a species, would we be able to say that it meets the technical definition of "endangered"? Would we say that this population is "threatened with imminent extinction or extirpation throughout all or a significant portion of its Canadian range" (Belcher et al., to be published)?

In this paper, I will argue that Saskatchewan's rural population is under threat because its numbers are declining and its habitat is eroding. If this pattern is not reversed, this population will become endangered.

RURAL COMMUNITY AND SUSTAINABLE DEVELOPMENT

Rural human populations (like urban populations) live in communities. The term community is notoriously difficult to pin down. One author identified ninety-four different definitions (Hillery 1955). Some people associate community with place - the town where I grew up. Others associate it with belonging - my community is where I belong, not necessarily where I live. I want to use it as an inclusive term. Communities need to be personal and intimate networks of relationship to which one can belong. They also need to have a material base in which they are constituted. They need to include organizations, institutions and places (Lind 1995). Like culture, friendship, and family life, these "...communities provide settings within which people grow and flourish and within which subgroups are nourished and protected. This establishes a presumption of moral worth..." (Selznick 1992).

In this sense, communities constitute a kind of physical and social habitat for human populations. When communities are destroyed, people fail to grow and flourish. They wither and die. They become endangered.

When habitat erodes and species become endangered, it is common to respond with approaches based on general conceptions of "sustainability", and specifically with conceptions of "sustainable development".

In the 1986 Bruntland Report, the term sustainable development was defined as meeting "...the needs of the present without compromising the ability of future generations to meet their own needs". Coming out of a Church context, I am aware of a slightly different history to the term "sustainability". Throughout the late 1970s and the 1980s, the theme of the World Council of Churches was the creation of a "Just, Participatory and Sustainable Society". This was influenced by a 1974 consultation of scientists, theologians and economists held in Bucharest (WCC 1974) in response to the report issued by the Club of Rome, "Limits To Growth".

Though earlier statements had used the term "sustainability" to refer to the sustained yield of forests and fisheries, the 1974 statement described as a goal a "sustainable society" where "...each individual can feel secure that his quality of life will be maintained or improved..." (Rasmussen 1996).

It went on to describe four characteristics of such a society. The first was an equitable distribution of the earth's resources and an opportunity for everyone to participate in decisions about them. The second characteristic was a pattern of use whereby our need for food was less than our supply and our emission of pollutants was less than the ecosystem's ability to absorb them. The third characteristic was a rate of consuming non-renewable resources that was slower than our technological capacity to develop new ones. The fourth characteristic was a level of human activity that was not put at risk by natural cycles of climate change. These characteristics show that from an early stage, the churches have been providing an ethical content to the term "sustainability".

While the theme of the World Council of Churches has moved on to "Justice, Peace and the Integrity of Creation", this history has caused the churches to regard skeptically the new fashion of speaking of sustainable development as if it held no contradictions. For example, the World Council of Churches made the following comments to the 5th Session of the UN Commission on Sustainable Development (WCC 1997):

"In our own work, we are regularly questioning the term 'sustainable development'. We find it often misused in order to legitimize current economic approaches which are premised on unlimited economic growth and a continuous and unregulated expansion of production and consumption for the world's rich. Thus to measure progress toward sustainable development in this context is to avoid challenging the very dynamics which are increasing the gap between the rich and the poor in the world and causing environmental destruction. We call upon governments, international institutions and people of good will to demonstrate moral courage and political will to confront the excesses of globalization."

In contrast to the term "sustainable development", the World Council of Churches has chosen to use the term "sustainable communities".

"We speak increasingly of 'sustainable community' because it implies the nurturing of equitable relationships both within the human family and also between humans and the rest of the ecological community - in other words, justice within the whole of God's creation." (WCC 1997).

Two issues are significant here. The first has to do with the term "development". From the churches' point of view, development is a characteristic of persons, and through development they become more fully human (Lind 1983). Insofar as economic globalization is what people mean by development, then it is this very process which most threatens sustainability, rendering the phrase "sustainable development" an oxymoron.

The second issue has to do with the term "sustainable". The churches define sustainability in terms of justice. It does not only have to do with ecosystems, as if humans were not part of those systems; and it does not only have to do with justice between the generations. It also has to do with justice between people right now. In this approach, the churches are echoing a theme frequently announced by third world voices, especially women (Slatter 1995). Larry Rasmussen (1996) identifies one of the differences between sustainable development and sustainable communities as the difference between an emphasis on "eco-efficiency" and an emphasis on "sufficiency". Advocates of eco-efficiency focus on the development of more environmentally benign technologies of production and consumption. This is not necessarily incompatible with economic globalization though it would still require major changes from current practice. Advocates of sufficiency focus on the redistribution of power and access to resources both within and between societies. This is incompatible with economic globalization in its current manifestation.

The shift in emphasis from sustainable development to sustainable communities reveals one of the key characteristics of globalization - that is forced migrations of large numbers of people. We call these people "uprooted". The World Council of Churches defines as uprooted "all those who are forced to leave their homelands for political, environmental and economic causes" (Programme Unit IV 1997). The movement of people is accelerating, according to the WCC, because of the "severe breakdown of economic and social conditions that once provided [them] with the means to survive in their traditional communities and in their own countries."

"Underlying this breakdown in conditions is the globalization of the world economy. This process continues to reproduce great and growing inequalities in wealth and incomes within and among countries. Emerging trade relations are working to the disadvantage of economically weaker countries."

"Burgeoning debt, coupled with externally imposed structural adjustment measures and restrictive fiscal policies are making it difficult for people to survive. At the same time many governments are divesting themselves of responsibility for social programmes." (Programme Unit IV 1997).

In Saskatchewan, rural people in general and farmers in particular, are experiencing a process of development characterized by adjustment to the new institutional arrangements of economic globalization. This process is unsustainable for rural communities.

THE SASKATCHEWAN CASE

In the late 1980s Saskatchewan farmers entered a period of profound crisis which is not yet finished (Lind 1995). From 1986 through 1993, the average value of farm land and buildings in Saskatchewan fell by 33%. Farm debt rose to $6 billion. The price of wheat, adjusted for inflation, dropped to the lowest price ever recorded. Reflecting even deeper shifts in institutional arrangements, the amount of interest paid by farmers rose from approximately $50 million/year in 1971 to over $450 million/year in 1981.

As you can well imagine, and as Figure 1 shows (Lind 1995), this confluence of factors produced a record of farm bankruptcies.

However, in Saskatchewan, farmers who are insolvent can be involved in both federal as well as provincial farm debt review processes. According to 1991 figures, of the 73% of farmers for whom data are available, 43% of those who went through farm debt review had their debt restructured or rescheduled, 43% quit their claim to the land and then leased it back from the lender, and 7% had some of their assets sold. This means that while bankruptcy statistics can show an accurate trend, the small numbers are misleading.

In Saskatchewan, statistics are gathered according to rural municipalities. There are roughly 300 rural municipalities (R.M.s) in the province with an average of 200 farmers in each R.M. As of July of 1989 there were 17 R.M.s where more than 20% of the farmers had gone through the farm debt review process. By Feb. of 1991 there were now 87 R.M.s where 20% or more of the farmers had gone through the farm debt review process. Just 6 months later, in September of 1991, there were 120 R.M.s where more than 20% of the farmers have gone before the review boards and 33 R.M.s where

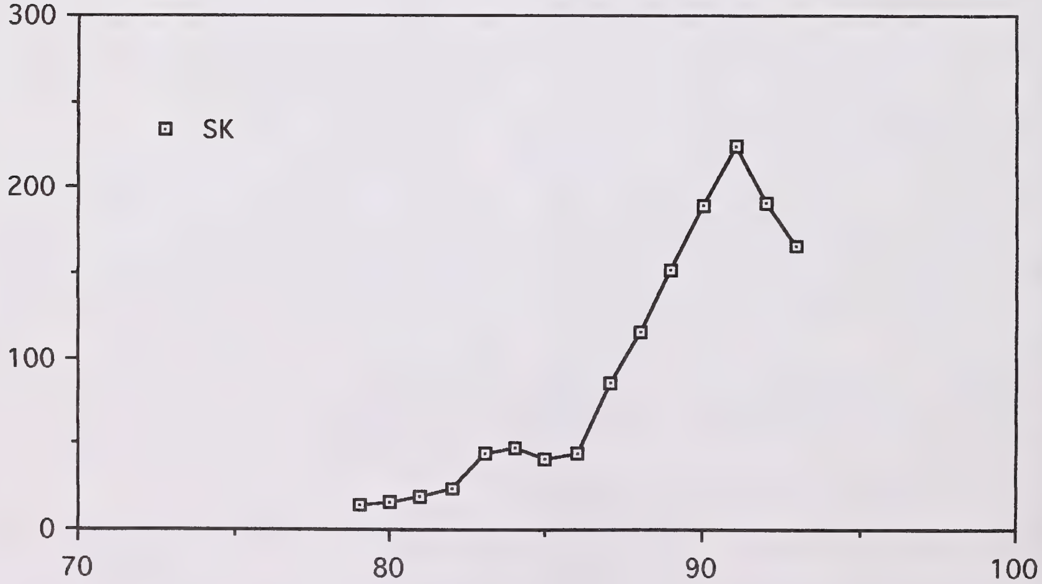

Figure 1. Farm bankruptcies in Saskatchewan from 1979 to 1993. Canada's 1993 total was 349 farm bankruptcies. Source: Industry Canada and Saskatchewan Agriculture and Food.

more than 30% of the farmers have gone through this process. By 1993 there were at least half a dozen rural municipalities where over 50% of the farmers had gone through the farm debt review process.

This indicates how rapidly the crisis spread. In response to these developments, the provincial government did two things. It required lenders to enter into a mandatory 5 year lease-back where they were repossessing property. Lenders did not object too strenuously to this because in most rural areas in the early 1990s there was no longer a functioning market for land. The second action the government took was to stop publicizing the figures for farm debt review.

There is another source for some of these data. One of the major sources of credit for farmers comes from a federal crown corporation known as the Farm Credit Corporation. Its loans to farmers have increased significantly in the last four years, possibly indicating that they are carrying a higher proportion of Canadian farm debt relative to banks. Between 1993 and 1997, the amount of loans approved by the FCC to Canadian farmers increased from $277 million/year to $1.432 billion/year (FCC 1997).

While Saskatchewan farmers carry 32.7% of FCC loans, the percentage of farm land carried on a lease basis by the FCC is almost entirely made up of Saskatchewan land. While the FCC carried 791,111 acres on its books on a leased basis, 743,410 acres or 93.6% of those acres were in Saskatchewan. The bulk of the land will come to the end of its lease period in between two and four years (FCC 1997).

It is on this basis that I say the crisis is not yet passed, in spite of the declaration by the provincial government in the fall of 1995 that the crisis was over. There are an estimated 2,000 to 3,000 farmers who will become completely dispossessed in the next four years. These farmers used to own the land they are currently farming and represent approximately 5% of the 1991 farm population.

THE URBANIZATION HYPOTHESIS

Some analysts interpret these changes in evolutionary terms as examples of adaptive behaviour. In 1992, Jack Stabler, Rose Olfert, and Murray Fulton published a study of declining populations in rural Saskatchewan between 1961 and 1990 (Stabler et al. 1992). Stabler and Olfert (1996) updated the study through 1995. The Stabler Olfert thesis is expressed in their title. We live in a world characterized by "urbanization" and this is what urbanization looks like in Saskatchewan.

"Along with the rest of North America, Saskatchewan was going through a continuing process of urbanization throughout the 1961-90 period. The population of the 598 subject communities was 538,666 in 1961 ... 679,622 in 1981 ... and by 1990 the population of these communities was 744,092.". During this period the total population of the province remained relatively constant (Stabler and Olfert 1996).

"As paved roads were extended into all regions of the province, shopping patterns shifted from the closest rural community to regional shopping centres where more stores, greater variety, and sometimes better quality and lower prices were available. Bypassing of intermediate-sized communities became common, and in response, new commercial development increasingly occurred in the larger centres as it withered away in the small communities." (Stabler and Olfert 1996).

While this reflects a shift from residency on the farm to residency in villages, towns and cities, the shift within these centres reflects movement within a hierarchy of trade centres from smaller to larger sites offering an increasingly complete set of wholesale and retail services. "Increasingly, the growing urban population chose to live in Saskatoon, Regina, and a few dozen larger communities at the top of the trade-centre hierarchy.... For the trade-centre system, further consolidation is inevitable." (Stabler and Olfert 1996).

Of the almost 600 communities studies, 450 "have no systematic role in today's trade system.... The bottom 255 places, with an average population of sixty-nine, are destined to disappear over the next several years." (Stabler and Olfert 1996).

Stabler and Olfert take a "functional approach to thinking about community". That is, all populations need "to have a means of finding employment, delivering grain, buying groceries, sending their children to school, accessing health care, socializing, etc." However, what this looks like in 1910 will be different than in 2010. "Most of our rural places came into existence in the early 20th century as grain delivery points... [and there is] nothing sacred about a spot where a grain elevator happened to be constructed in 1911." (Stabler and Olfert 1997).

In this sense, they stand with Ferdinand Toennies (1957) for gesellschaft (society) and against gemeinschaft (community). The German sociologist described society as modern, urban, and public. It is the result of free association and contract. It is rational. It stands over against community which he described as intimate, but also private, exclusive, and closed to strangers. By this description, it lacks a presumption of moral worth.

If rural villages or towns are not privileged then they have no prior claim to being sustainable. "We do not see the origin of the changes as being sinister but rather as a process of evolution." (Toennies 1957). In contrast, I do not view the most recent changes as being benign, nor do I view the dispossession of farm families as adaptive or evolutionary. While I agree that no single town has a prior right to continued existence, the broader definition of community and the breadth of the social and economic crisis in rural Saskatchewan lead me to a different analysis and response.

THE GLOBALIZATION HYPOTHESIS

Stabler and Olfert (1996) themselves identify some of the factors leading to a quite different analysis. Specifically, they identify the new institutional arrangements of free trade, a rise in government debts leading to cutbacks in infrastructure, decreasing political influence of rural populations, shifting conditions of employment for rural workers, and a changed ethical agenda as factors distinguishing the 1990s from the 30 years previous.

For example, "GATT is, in fact, only part of a movement toward an increasingly competitive world economy exemplified in North America by FTA and NAFTA. At the same time that freer trade will be beneficial to some sectors, it will present increased challenges to others." (Stabler and Olfert 1996).

"In other areas, lower levels of transfers from federal to provincial governments, in conjunction with a concerted effort to bring deficits under control, have resulted in reduced spending by the provincial government on health, education, welfare, and transportation, as well as on agriculture." (Stabler and Olfert 1996).

And again, "the ever-diminishing size of the rural population continuously erodes the influence of its representatives in legislative assemblies, making these difficult adjustments somewhat easier politically than in the past." (Stabler and Olfert 1996).

With regard to rural workers, Stabler and Olfert (1996) observe that "a sizable proportion of the labour force from rural areas now commutes daily to work in one of the communities in the top four functional categories."

Finally, the shift in ethical orientation is observed as follows: "In many ways the period studied (1960-1995) represents the interval during which the balance of market, institutional, and governmental influences shifted unequivocally from the more equity-oriented framework of the post World War II era (epitomized by the 1970s) to the more efficiency-oriented, competitive framework that will prevail into the twenty-first century." (Stabler and Olfert 1996).

In other words, Stabler and Olfert (1996) describe the conditions of globalization and the adjustment of political structures to it as the factors which separate the 1990s from the earlier period. By not identifying this cluster of issues as distinctive, however, they fail to see the difference between the current crisis and earlier periods of modernization.

In this analysis, I am not interpreting the displacement of 5% to 10% of the farming population as rational consumer choice for an urban, modern lifestyle. Rather I am discerning the link between farm revenues below the cost of production and the increase in off-farm work. This calls for a re-interpretation of changes in rural life. Philip McMichael (to be published) claims that we are just now coming to "...the end of a period of world history during which the 'rural' was regarded as a mere residue to pre-modern life. Its stimulus is the phenomenon of 'globalization'." This process is causing people to become uprooted. The World Council of Churches identifies the same phenomena, changing trade relations, burgeoning debt, and programs of structural adjustment as the factors that combine to create uprooted peoples.

I recognize that the numbers in rural Saskatchewan pale in comparison to the numbers elsewhere in the world. For example, "...in Brazil, the government's planned, concerted efforts to modernize and rationalize agriculture from small holdings producing food for domestic consumption into a capital-intensive, export-oriented machine for earning foreign exchange resulted in the uprooting of 28.4 million people between 1960 and 1980 — a number greater than the entire population of Argentina." (Rich 1994). Even so, while the numbers are drastically smaller, the process is similar. An economic process is taken to be inevitable and so all political energies are channeled into accommodating to the new arrangements rather than directing the economic process according to a different political will.

Though analysts like Stabler and Olfert (1996) might be expected to argue that such an approach is folly, in their study they do describe just such an example. "Melville has had a somewhat unusual history. Its location relative to Yorkton has historically constrained its development as a trade and service centre. This had been offset, however, by other activities that provided employment and maintained its population at a higher level than could have been supported by its trade-centre functions alone.... [Its] ups and downs reflect the changing base of its economy, which was dependent upon the railroad for many jobs until the early 1980s. Consolidation led to the loss of many of these jobs, a decline in the local economy, and classification as a Partial Shopping Centre [down from a Complete Shopping Centre] in 1990."

"Melville's economy received a major boost in the mid-1980s when the provincial government relocated the main offices of Saskatchewan Crop Insurance to that city." It was reclassified as a Complete Shopping Centre in 1995. So, in spite of having concluded that urban consolidation was, and is, inevitable, Stabler and Olfert (1996) describe the kinds of political and economic factors that can accomplish a reversal of this trend. In addition, their policy prescription of regionally based (rather than town based) planning initiatives can also be used to effect alternative futures.

In earlier work I have analyzed globalization in Polanyian terms (Polanyi 1994). That is, we are living through a revolution that is like the Industrial Revolution in its scope. Only now it is not the regional markets of a pre-modern Europe that are being united. Now it is the separated markets of national economies that have been linked together for form a single global market. In the linking, the new global economy has become disembedded from the institutional constraints imposed by nation states. Instead of national societies determining the character of regional markets, it is now a global market that is determining the character of national states.

In this most recent revolution, money is the key in two ways. The revolution called globalization has been led by the markets for finance capital. Indeed, the trading of currency now surpasses the trade in goods and services by more than twenty to one (Lind 1996). This has led to the weakening of the power of nation states and central banks relative to the foreign exchange and futures markets. Indonesia is only the latest country to experience this.

It is also the key in conceptual terms. In a market economy, money allows for the exchange of that which is otherwise incommensurable. "All goods and services have their price or monetary equivalent in a market economy, thereby creating an artificial common denominator for the most diverse or intrinsically unrelated items. This dissolves their specificity in an acid bath of 'equivalent monetary value'. A woodlot is worth a new car is worth one-half of a child's education is worth two tickets to Bali." (Harries-Jones et al. 1996).

It is this transformative power of money that allows us to consider as real the fiction of "sustainable development". What we are sustaining is our ability to convert like to unlike through the power of a market price.

The Canadian churches recognize this when they describe the contradictory tendencies in rural Canadian life. "Agriculture is torn between the desire of farmers to feed the world while making a fair income, and those who see agriculture as a capital intensive, high technology, international industry" (Canadian Council of Churches 1997). When faced with these choices, the Canadian churches have opted for an emphasis on "sustainable communities" rather than "sustainable development". "Governments and churches", they argue, "should support policies and programs which strengthen rural communities including land tenure reform" (Canadian Council of Churches 1997). In making these choices, they are opting against what they see as a kind of "green globalization" as well as against more traditional forms of economic domination. They are opting for "viable communities and sustainable livelihoods within them" (Rasmussen 1996).

SUMMARY

In summary, the physical and social habitat of the rural population in Saskatchewan is under threat from a combination of forces which lead to diminished livelihoods, reduced services, eroding infrastructure, and declining numbers. If we were describing a non-human animal population, we would classify them as being "threatened" with becoming "endangered".

The increased displacement of peoples is one of the signs of the unsustainability of development through globalization. This uprooting of peoples is seen on a massive scale in the Third World (that part of the world with the majority of the population but a minority of economic power) but the essential process is also visible here in Canada's rural, western backyard - Saskatchewan.

The crisis of Saskatchewan farmers is not over in spite of what the provincial government might say. The crisis is also not a residue of the urbanization of modernity. It is a crisis of sustainability because globalization changes the balance of power between rural and urban populations. This makes it not a question of efficiency but a question of justice. In spite of their conclusions, Stabler and Olfert (1996) provide some of the data required to understand the way in which the displacement of the rural Saskatchewan population is a function of the same processes of globalization afflicting the rest of the world. With a different interpretive framework, they also provide some clues about how political power can be used to create counter trends toward a more just society.

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CONCLUDING REMARKS

Pete Ewins

World Wildlife Fund, 504 - 90 Eglinton Avenue E, Toronto, Ontario M4P 2Z7

This has been a hugely successful gathering of scientists, ranchers, conservationists, producers, ecology students, and government officers. Hugely successful primarily because this diverse group of individuals (call them "stakeholders" or "stockholders" if you prefer!) have been together for three days, focussing on a wide range of projects, concerns, issues, and approaches. Problems for all, which can be better solved by working together. In the past this has not always been the case, and so valuable time and resources have been wasted in conflict situations. This meeting is perhaps one of Canada's best examples of people from all walks of life working together to seek new ways of achieving lasting conservation of natural resources, at the same time as allowing people to make an honest living off the land.

I was struck in virtually every presentation by the conference's acronym - PCAES. The themes coming out most clearly related to this acronym: P for People, C for Critters, A for Agriculture, E for Economics, and S for Sustainability. However, S could also have stood for Scale. And it is the issue of scale on which I would like to focus. This is central to all conservation issues in the Prairies, as in many other parts of the world, and includes considerations of both timescale and spatial scale.

The importance of spatial scale is often very unclear when considering what to do with a small corner of a field with relic grasslands, or a small pothole with only a couple of pairs of ducks. But it is the cumulative value of these remaining pockets of natural habitat which make the Prairies such a rich wildlife area. "Think globally, act locally" is a phrase one often hears. It can probably never be spoken often enough, for it is only by thinking about the bigger picture that one can hope to achieve any form of sustainable land use practice. Prof. Dave Schindler in Alberta turned this the other way round, and described the demise of natural habitats one piece at a time as "Like being nibbled to death by ducks"!

Temporal scale is the aspect I found most illuminating in many talks, notably those by Fritz Knopf, Lorne Fitch, and Noel McNaughton. So often we humans focus, especially in this latter part of the 20th Century, on timeframes of three to five years, or a decade, or perhaps a human lifespan. However, when one tries, or is able, to dig backwards in time, to see what habitats and animal communities were like 100 years ago or more, we usually learn very important lessons.

The former mantra taught in Universities and High Schools that ecosystems usually reached some sort of equilibrium and balanced condition is now widely regarded to be incorrect. Why should we try to freeze the frame at a 1950s picture, or a 1970s picture? Plant and animal communities change, and have always been changing. The ecosystems we mortals have regarded as static are continually changing, albeit on a different timescale. Wildlife species have been on the move for centuries, adapting to shifting weather patterns, fire, drought, floods. Therefore we must ensure that we leave sufficient breathing space and flexibility for these species to change and adapt and move. If we don't we will lose them of course! But it is we humans who have established a relatively static system of farming and livelihoods, where we are relatively inflexible and unable or poorly prepared to move when conditions change.

Clearly the key is habitat conservation, and some species simply can not adapt to small, fragmented patches of natural habitat. If we don't provide such areas, and linkage between patches, then these species will vanish. I was particularly struck by the marvellous commitment from the Saskatchewan Stock Growers' Association, led by Miles Andreson, to raising stock on natural grasslands, range which will provide a home for his cattle in the long-term, well beyond his lifespan, as well as a rich array of plant and animal species dependent on this wonderful habitat. This is the ethic which has all too often been lost, but one which together we can rebuild, and make sure that in future there are fewer species on the Prairies which have to be classified as Endangered - including humans!

On behalf of WWF I would like to congratulate the organisers and participants of this conference for making this such a successful weekend. You are a dedicated, committed bunch, with a great sense of humour and spirit. I wish you well in your efforts in the future, and look forward immensely to the next conference.

POSTERS

THE STATUS OF SAGE GROUSE *(Centrocercus urophasianus urophasianus)* IN CANADA

Cameron L. Aldridge

Department of Biology, University of Regina, Regina, Saskatchewan S4S 0A2

Abstract: The sage grouse (*Crentrocercus urophasianus*) is the largest North American grouse and depends on sagebrush (*Artemisia spp.*) for diet and protective cover. The association with sagebrush limits the range of sage grouse to the range of sagebrush. As a result of the loss of native sagebrush-grasslands, the range of sage grouse has decreased by over 50% since the turn of the century. Sage grouse are considered a "threatened" species in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

In Canada, sage grouse are at the northern edge of the species' range, occurring only in extreme southeastern Alberta and southwestern Saskatchewan. Population trends based on spring lek surveys indicate that populations have experienced an 80% decrease from numbers in the early 1980s in Alberta, or from the late 1980s in Saskatchewan. The decline occurring in the rest of the range, although thought to be less severe, is most often attributed to the loss of habitat. Degradation of sagebrush habitat has resulted from human agricultural developments, oil and gas exploration, vehicular traffic, and the drought of the early 1980s. Sage grouse have been extirpated from British Columbia and three of at least 15 U.S. states known to previously support populations. In 1997, the Canadian sage grouse population was estimated at between 513 and 849 individuals (Aldridge 1998), which may not be high enough to sustain a viable population.

INTRODUCTION

Sage grouse (*Centrocercus urophasianus*) are found almost exclusively where sagebrush-grasslands occur. The range of the native sagebrush habitat has been decreased by approximately two and a half million ha, which ultimately reduced the range of the sage grouse (Braun 1995). The eastern subspecies (*C. u. urophasianus*) occurs in Canada at the northern edge of its range, in extreme southeastern Alberta and southwestern Saskatchewan. In Canada, sage grouse were officially listed as a "threatened" species in 1997 by the Committee on the Status of Endangered Wildlife In Canada (COSEWIC) due to their limited range, specific habitat requirements, and decline in numbers over the past 30 years. This paper is adapted from the Alberta Wildlife Status Report on the Sage Grouse in Alberta (Aldridge 1998).

HABITAT

In Canada, sage grouse are found within the range of silver sagebrush (*Artemisia cana*) on the semi-arid mixed-grass prairie. In this area, the mean annual precipitation is about 310 mm, and temperatures for July and January average 19.1 and -14.5° C, respectively (McAdam 1997). Essentially flat, the prairie contains small knolls or hills and is often interrupted by vast coulees that lead to numerous creeks and river tributaries. Although the sage grouse have a close association with sagebrush habitats, specific habitat requirements vary throughout the year. It is important that areas contain habitats which satisfy requirements for strutting grounds, nesting areas, feeding and loafing sites, brood rearing sites, and possibly wintering grounds (Beck 1977, Eng and Schladweiler 1972, Klebenow 1969, Wallestad and Pyrah 1974).

Strutting Grounds

Areas in which displaying males are highly visible to females during the spring mating season are used as strutting grounds (leks). Leks range in size from 0.04 ha to as large as 4 ha, and are very traditional, with some remaining active for upwards of 100 years (Dalke et al. 1963). These are typically flat, open areas, such as dried mud flats or valley bottoms (Dalke et al. 1963, Patterson 1952, Peterson 1970, Scott 1944) that are often slightly lower than surrounding areas and are usually located near small creeks (pers. obs., W. Harris pers. comm.). Leks themselves typically have little vegetation, but are surrounded by sagebrush flats that are important as feeding and roosting sites (Clark and Dube 1984, Patterson 1952, Peterson 1970, Scott 1944). Spring daytime roosting sites of males have a canopy coverage of 20 to 50%, and consist of plants that are <30 cm tall (Wallestad and Schladweiler 1974, Wallestad 1975).

Nesting Areas

Nesting habitat is associated with sagebrush flats surrounding strutting grounds. Despite the apparent association of nests with leks, Wakkinen et al. (1992) found that nest distribution with respect to leks was random, even though 92% of nests in the southeastern Idaho study area occurred within 3 km of a lek. Nests are almost exclusively placed under sagebrush (Braun et al. 1976, Gates 1985, Patterson 1952, Wallestad and Pyrah 1974) which typically has fairly dense canopy coverage (20 to 50%; Klebenow 1969, Patterson 1952, Wallestad and Pyrah 1974).

Brood Rearing

In early summer, broods concentrate in areas that have sparse sagebrush cover and are more open and moist (Drut et al. 1994b, Klebenow 1969, Patterson 1952, Wallestad 1971). During late brood rearing and breakup, hens and broods searching for succulent forbs move further into moist areas (wetlands and wet meadows), often near open water (Drut et al. 1994b, Klebenow 1969, Patterson 1952, Wallestad 1971). Birds return to dense sagebrush in late summer and fall before moving to wintering grounds (Drut et al. 1994a, Patterson 1952, Wallestad 1971).

Wintering Habitat

During the winter, sagebrush is extremely important as it makes up 100% of the diet of sage grouse and provides cover from inclement weather (Johnsgard 1973, 1983, Patterson 1952, Remington and Braun 1985, Wallestad et al. 1975). Winter locations are usually at lower elevations such as drainage basins (Hupp and Braun 1989b, Patterson 1952), where sagebrush is dense enough and tall enough to remain above snow cover (Johnsgard 1973, Eng and Schladweiler 1972).

CONSERVATION BIOLOGY

General Biology

Sage grouse are the largest North American grouse (Beck and Braun 1978) and exhibit extreme sexual dimorphism, with females and males weighing about 1080 and 2410 grams, respectively (Johnsgard 1973, 1983, Nelson and Martin 1953). Weight fluctuates throughout the year, with the maximum being attained during the breeding season (April to May; Beck and Braun 1978, Hupp and Braun 1991, Patterson 1952). Beck and Braun (1978) suggest that the overwinter weight gain is necessary to meet the high energy demands of breeding rather than for overwinter survival. Male sage grouse in Alberta are larger than throughout the rest of their range (breeding weight estimated at 3290 grams; Aldridge 1998), which may be an adaptation to the longer, more extreme weather conditions at the northern edge of the species' range.

Lek Behaviour

Males begin returning to lek sites in late winter, and begin displaying and establishing territories as soon as snow disappears. Older cocks arrive first, and obtain the most central territories (Patterson 1952). If yearling males manage to obtain a territory (mid April in Idaho and Montana, Dalke et al. 1963, Eng 1963; late April to early May in Alberta, Aldridge 1997), it is usually after the period of peak female attendance, and they are usually displaced to the periphery. During population lows, smaller dancing grounds tend to be abandoned (Dalke et al. 1963). Males will attend and display at leks at both dusk and dawn, but activity peaks during the hour surrounding sunrise (Johnsgard 1983, Patterson 1952). The male display is used both to attract females and defend a territory from other males (see Johnsgard 1983 or Patterson 1952 for detailed description). Both males and females show a strong tendency to return to the same strutting ground each year (Berry and Eng 1985, Dalke et al. 1963, Emmons and Braun 1984.

Nesting

After mating, females move to nest sites located in close proximity to leks, and typically near previous years' nest sites (Fischer et al. 1993, Patterson 1952). Mean clutch size is usually 7 to 9 eggs (Anonymous 1997), and in Alberta, peak hatching occurs in early June (Clewes 1968). In Idaho, Connelly et al. (1993) found that 78% of all adult females and 55% of yearlings initiated a nest; 52% of both age groups produced a clutch. Reproductive success in Alberta has declined in recent years. Mean brood size from 1967 to 1976 gradually decreased from 4.4 to 3 chicks per hen (both n=20; Windberg 1976) and in 1985, brood size was 3.4 (n=29; Banasch 1985). Crawford and Lutz (1985) reported similar trends in Idaho, with brood sizes decreasing from 4.5 chicks per hen in the late 1950s, to 3.3 in the early 1980s. They also reported that the percentage of adults with broods declined from 55% to only 9% over the same time period. Patterson (1952) found that 20% of eggs hatched and produced chicks that survived to the age of four months.

Non-breeding Season

In late summer and fall, sage grouse congregate in sexually segregated flocks for movements to wintering grounds (September to December) (Beck 1977, Connelly et al. 1988, Eng and Schladweiler 1972). Distances moved from breeding to wintering ranges average 7.9 to 30 km for sage grouse in southern populations (Beck 1977, Schoenberg 1982). However, one-way migrations of 80 to 160 km have been recorded (Connelly et al. 1988, Dalke et al. 1963, Patterson 1952). The longest reported migration movements are usually of birds moving to lower elevations (see Connelly et al. 1988, Patterson 1952).

In Montana, sage grouse populations are considered non-migratory, with minimal movements occurring between winter and summer ranges (Eng and Schladweiler 1972). Wintering grounds in southeastern Idaho also overlap with spring and summer ranges (Connelly et al. 1988). Landscape features in Alberta and Saskatchewan are similar to Montana, and thus, sage grouse in Canada are probably non-migratory. Beck (1977) found that sage grouse wintering areas composed only 7% of sagebrush habitat, suggesting that winter habitat may be the most limited resource (Beck 1977, Eng and Schladweiler 1972, Patterson 1952, Remington and Braun 1985).

Diet

Sage grouse lack the muscular gizzard necessary for the grinding of seeds and other hard materials (Paterson 1952, Remington and Braun 1985). Consequently, their diet is limited to soft vegetation such as sagebrush leaves and buds. Sagebrush constitutes 62% of the year round diet (Wallestad et al. 1975) and makes up 100% of the diet in winter (Patterson 1952). All sage grouse shift their diet to include some lush forbs in the summer (Barnett and Crawford 1994). Forbs make up 75% of the diet of juvenile sage grouse that are <12 weeks of age (Peterson 1970). Insects are also an important component of the diet of juveniles (Drut et al. 1994b, Klebenow and Gray 1968, Patterson 1952, Peterson 1970), and make up as much as 60% of the diet of one week old chicks in the wild (Peterson 1970).

Survival

Annual adult survival has been estimated at 30 to 60% (see Johnsgard 1973, Beck and Braun 1978). Adult males often have lower survival rates than do yearlings (33.7 versus 56.1%), and it is thought to be related to weight losses incurred by adults during courtship (Beck and Braun 1978). Juvenile mortality may be high, with large numbers succumbing to disease and predation (Patterson 1952). The major predators of adult birds are hawks, eagles, coyotes (*Canis latrans*) and badgers (*Taxidea taxus*), while ground squirrels, striped skunks (*Mephitis mephitis*), magpies (*Pica pica*), American crows (*Corvus brachyrhynchos*) and coyotes are known to take eggs (Patterson 1952, McAdam 1997).

DISTRIBUTION

Canada

Sage grouse presently occur in a 6,000 km^2 area in southeastern Alberta and Saskatchewan (see 1997 range; Figure 1). This distribution is based on known locations of active strutting grounds. Sage grouse in Canada probably represent a continuous population

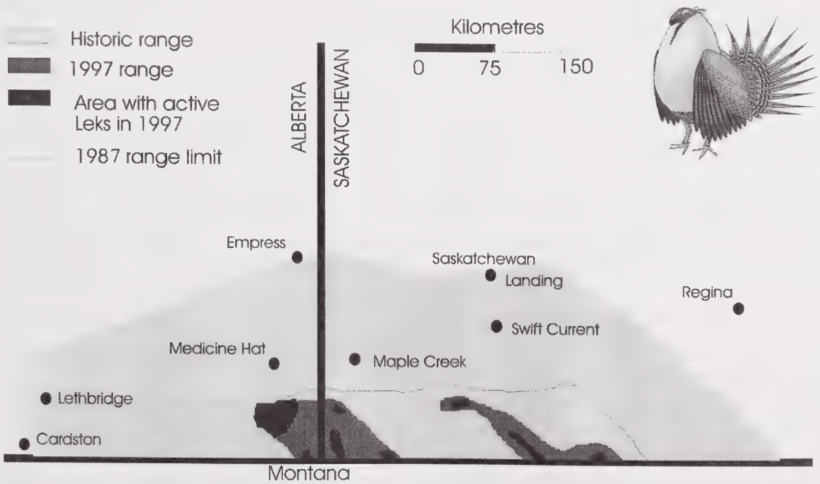

Figure 1. Range of sage grouse in Canada. The historical range is based on anecdotal sightings of sage grouse prior to the commencement of lek surveys. The 1997 range limit is based on the locations of active leks that year. The 1987 range limit is shown to illustrate the range contraction.

Figure 2. Current (solid line) and known historic (dashed line) distribution of the eastern (E) and western (W) subspecies of the sage grouse (adapted from Johnsgard 1983). The current distribution is not continuous and is more fragmented than indicated.

which likely extends into Montana to the south (see Figure 2). It is not known where Canadian birds winter, but it is suspected that they are non-migratory. Historically, the range of the sage grouse in Canada was much greater (about 100,000 km^2; see Figure 1), with the species likely occurring over the historic range of sagebrush.

Other Areas

The eastern subspecies (*C. u. urophasianus*) which occurs in Canada, is the most common and widespread. The western subspecies (*C. u. phaios*) is present in smaller numbers from eastern Washington to southeastern Oregon, and historically occurred in the southern Okanagan valley of British Columbia (Figure 2). Today, sage grouse are considered extirpated from British Columbia and at least three of 15 U.S. states (Nebraska, New Mexico and Oklahoma; see Figure 2) (Anonymous 1997, Johnsgard 1973, 1983). Range contractions have also occurred in other parts of the species' range, where available habitat continues to disappear (Braun 1995, Eng and Schladweiler 1972, Swenson et al. 1987, Wallestad et al. 1975).

POPULATION SIZE AND TRENDS

The most cost effective and time efficient method of obtaining data on sage grouse to estimate population size is through lek surveys. These represent the maximum count of all male sage grouse displaying on a strutting ground during the spring mating season (Beck and Braun 1980).

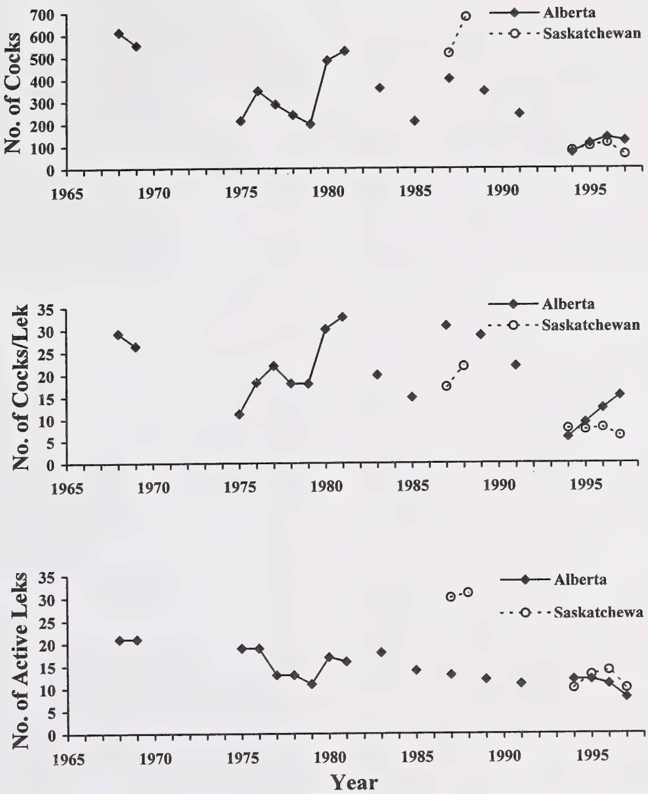

Figure 3. Population trends for sage grouse in Canada over the past 30 years based on the number of cocks, number of cocks per lek, and number of active leks. Years with sampling effort of less than eight surveyed leks are not included.

Canada

Sage grouse lek surveys have been performed independently in both Alberta and Saskatchewan, and for this reason population trends are analyzed as separate data (Figure 3). In Alberta, surveys have been performed on average every two years since 1968, although gaps as long as five years have occurred (Figure 3). During the first two years (1968-69) and in the early 1980s, sage grouse numbers peaked, and approached 600 males on about 20 leks, with greater than 25 cocks/lek on average (Figure 3). In Saskatchewan, the first surveys performed in 1987 and 1988 peaked at about 600 males, but there were 30 active leks with about 20 cocks/lek (Figure 3). Since the surveys began, there has been a general decline in numbers, such that in 1997, there were only eight, and 10 active leks supporting 122 and 61 males, in Alberta and Saskatchewan respectively (Figure 3).

Lek surveys suggest that the overall Canadian sage grouse population has declined by about 80% from known maximum levels. However, the exact rate of decline is difficult to determine, as sampling effort has been inconsistent among years (Aldridge 1997, Madsen 1995, McAdam 1997). It is also difficult to determine from some reports whether leks that apparently contained no birds were actually located and surveyed. The determination of trends is further complicated by population cycles which last from five to ten years (Figure 3; see also Aldridge 1998, McAdam 1997, Patterson 1952). Based on 1997 lek surveys, the total spring population of sage grouse in Canada has been estimated at between 549 and 813 individuals (see Aldridge 1998). It has been suggested that 500-5000 individuals may be required to sustain a viable population (Anonymous 1997, Braun 1995).

Other Areas

Declines in sage grouse populations have also been reported in the United States. By 1983, sage grouse in Oregon had declined by approximately 60% from levels in 1940 (Crawford and Lutz 1985). Similarly, sage grouse numbers in Colorado have decreased by over 50% since the early 1900s (Braun 1995). Overall, the continental decline in sage grouse abundance mirrors the loss of sagebrush habitat (Braun 1995, Braun et al. 1977, Eng and Schladweiler 1972, Swenson et al. 1987, Wallestad et al. 1975).

LIMITING FACTORS

Population declines of sage grouse on the Great Plains have been attributed primarily to loss of sagebrush habitat. However, a number of more localized disturbances, such as industrial development, have contributed to the loss of suitable habitat, and declines are likely due to a combination of factors (outlined below).

Agricultural Practices

The demand for productive agricultural land in the 1900s in North America resulted in massive sagebrush eradication programs. This decreased the range of sagebrush and thus potential sage grouse habitat by an estimated two and a half million ha from 1952 to 1977 (Braun et al. 1977). Cultivation of sagebrush-grasslands has decreased available habitat (Dalke et al. 1963, Patterson 1952, Wallestad and Pyrah 1974). The ploughing of 16% of sage grouse habitat in Montana, including 30% of the wintering range, reduced sage grouse numbers by 73% (Swenson et al. 1987).

Overgrazing has also been suggested as a main reason why sage grouse populations have declined (Dalke et al. 1963, Johnsgard 1973, 1983). The decline documented in Alberta lek surveys since 1968 corresponds with increased numbers of livestock grazing in the southeastern part of the province (Windberg 1975). The removal of cover by cattle can impact sage grouse populations either by reducing habitat suitability, or by increasing the exposure of birds to predators or extreme weather.

Oil and Gas Exploration

Oil and gas exploration and extraction are very active within the Canadian range of sage grouse. The removal of vegetation for well sites, access roads and associated facilities can reduce and fragment suitable habitat and may disrupt breeding activities. Six traditional strutting grounds in Alberta, four of which are no longer active, are known to have been disturbed by oil and gas exploration activities (pers. obs., Dube 1991).

Roadways and Traffic

More heavily used roads and highways cause sage grouse mortalities and fragmentation of habitat (Patterson 1952). Sage grouse travel on the ground between leks and foraging sites, and some have also been known to form leks on well used roads (Patterson 1952), which has obvious detrimental effects on populations. In addition, roadways may render leks more visible to humans, which could lead to the abandonment of strutting grounds if they are continually disturbed by interested onlookers.

Climate

Sage grouse are fairly robust birds, yet climatic conditions may be limiting in Canada. Short summers and particularly harsh winters may limit the ability of individuals to find enough food in winter months, decreasing lipid reserves necessary for reproduction (Back et al. 1987, Hupp and Braun 1989a) and possibly lowering overwinter survival (Back et al. 1987). Particularly wet and cool conditions during incubation and hatching periods in the spring can drastically reduce productivity (Weichel and Hjertaas 1992). Drought might also limit the availability of lush vegetation important in the diet of all sage grouse during the summer. The drought of the 1980s may have limited productivity and, when combined with consistent cattle stocking rates, a substantial loss of vegetative cover could have resulted in increased predation and lowered overwinter survival (K. Lungle pers. comm.).

STATUS DESIGNATIONS

Canada

Sage grouse were listed as a "threatened" species in 1997 by COSEWIC and are likely to be placed on the endangered species list in Canada if limiting factors are not reversed. In 1996, due to concern over the decline in population numbers, it was decided that the hunting of sage grouse in Alberta would be closed indefinitely for the first time since 1967. In a 1996 review of the status of wildlife in Alberta, sage grouse were included on the "Blue List" of species which are considered to be at risk. Sage grouse have tentatively been classified as an "endangered" species in the province of Saskatchewan (R.M. Brigham Pers. Comm.).

Other Areas

In the United States, status designations vary by state and in some, such as Washington, sage grouse are listed as endangered (C. Braun Pers. Comm.). In the United States, these birds are considered an upland gamebird and are still hunted in most states.

FUTURE WORK IN CANADA

As a follow up to the 1997 COSEWIC listing of sage grouse as a "threatened" species in Canada, it is recommended that a recovery plan be developed. Acting on the advice of COSEWIC, the recovery team will convene a team of biologists and other interested parties in early 1998 to formulate a recovery plan for the management of sage grouse in Canada. Also set to begin in 1998 is a two year study of the behavioural ecology of sage grouse in Canada. The objectives of this work will be to (1) monitor movements of individual females to assess habitat selection and importance throughout different life history stages; (2) determine reproductive success and survival at different life history stages i.e. clutch size, brood size; (3) compare life history strategies of sage grouse in Canada with southern conspecifics. Hopefully, this research will provide the recovery team and wildlife managers with a better understanding of the basic biology and life history strategies of sage grouse in Canada.

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WINTER ABUNDANCE AND DISTRIBUTION OF SMALL MAMMALS IN THE CANADIAN MIXED-GRASS PRAIRIES AND IMPLICATIONS FOR THE SWIFT FOX

Erika E. Almási-Klausz

Canadian Wildlife Service, 4999-98 Avenue, Edmonton, Alberta T6B 2X3

Ludwig N. Carbyn

Canadian Wildlife Service, 5320-122 Street, Edmonton, Alberta T6H 3S5

Abstract: The relationship of vegetation-snow-small mammal demographics was investigated in swift fox (*Vulpes velox*) habitat along roadside ditches, coulees, and uplands in the mixed-grass prairies of southern Alberta and Saskatchewan during early (November), mid (January-February), and late (March-April) winter of 1995-1996. Mark-recapture methods of trapping resulted in a total of 163 small mammals in 9,360 trap-nights. Species diversity was low and deer mice (*Peromyscus maniculatus*) comprised 96.0% of the total catch, while shrews (*Sorex sp.*) constituted the remaining 4.0%. *Peromyscus* populations were localized during the winter and reproduction ceased from early November to early April. In early winter, *P. maniculatus* was more frequently captured in uplands, but in late winter, it was more abundant in linear (roadside and coulee) habitats in regions with less snow cover. Early winter trapping resulted in highest abundance values while there was a significant decline from early to late winter, except in one study area, where spring-like conditions arrived sooner, at which time males travelled greater distances. It was hypothesized that low prey abundance, especially during the latter part of winter, probably contributes to higher swift fox mortality. Therefore, it is proposed that swift fox releases should be optimized when and where small mammal prey is the most abundant.

INTRODUCTION

The swift fox (*Vulpes velox*), once occupied much of the Canadian mixed-grass prairies. However, since the turn of the century the range has declined, both in Canada and the United States. The last documented swift fox record in Canada was in 1938 near Manyberries, Alberta (Soper 1964).

In 1983, reintroduction efforts were initiated to reestablish swift fox in its former Canadian range. To date, approximately 290 swift foxes have become successfully established out of the approximate 900 captive and wild-released foxes (Cotterill 1997). However, the long-term viability of the population is uncertain due to various factors that may limit survival, such as coyote predation, food availability and accessibility, and habitat suitability.

This study focuses on the abundance and distribution of small mammals during the winter, at which time alternative food such as song birds, reptiles, amphibians, insects and ground squirrels become unavailable. Studies suggest that swift fox rely largely on small mammals for food during the winter (Hines and Case 1991, Uresk and Sharps 1986). If this food source becomes limited and alternative winter prey such as lagomorphs are not readily available or accessible, the result may be increased mortality and hence a decline in swift fox numbers. A similar scenario was observed for the closely related kit fox (*Vulpes macrotis*) in south-central California where numbers declined after the main prey base of mice became scarce (White et al. 1996). Small mammal populations reach their maximum in early winter (November) and then decline until spring when reproduction resumes (Wolff 1989). Therefore, small mammal abundance at the beginning of winter is one indication of how plentiful and available this prey will be during the winter.

In addition to the abundance of small mammal prey, it is also important to consider factors that may influence the distribution of small mammals such as the surrounding vegetation and the accumulation of snow in different habitat types. Upland habitats, for example, consist of sparse and low vegetation with less accumulation of denser snow, while linear habitats such as roadsides and coulees exhibit higher and denser vegetation with greater accumulation of softer snow (Coulianos and Johnels 1963). Therefore, upland habitats where snow cover is less and exposure to the elements is thus greater, may be less favoured by small mammals during the winter (Formozov 1964).

The aim of this study was to investigate the relative abundance and distribution of small mammals during the winter in three different prairie habitats (roadside, coulee and upland) and to determine how these habitats varied in vegetative structure and cover, and snow depth.

METHODS

The study was conducted during the winter of 1995-1996 in present swift fox range in southern Saskatchewan and Alberta, including: the Onefour Grazing Research Station in SE Alberta (49° 05' N, 110° 30' W); the Alberta/Montana/Saskatchewan Border region near Consul, Saskatchewan on the Govenlock Community Pasture (49° 02' N, 110° 50' W), 75 km east of Onefour; and the Dixon Provincial Community Pasture surrounding the West Block of Grasslands National Park near Val Marie, Saskatchewan (49° 14' N, 107° 44' W), 250 km east of the Border region. Cattle were grazed in these regions from May to October.

Three replicates of trapping transects were established in each of upland, coulee, and roadside habitats within each study area. Vegetation characteristics of each habitat along each trapping transect were estimated based on percent cover of shrub, grass, forb, cactus, moss, lichen, stone, cattle dung and bare ground within a 1 m^2 gridded quadrat, along with vegetation height and litter depth measurements. During early (November), mid (January-February), and late winter (March-April), snow depth measurements were taken along the trapping transects. Small mammals were live-trapped during these winter periods. Trapping transects consisted of thirty long-worth traps wrapped in bubble-wrap, spaced at 30 m intervals and their positions marked with pin flags. Each trap was baited with a peanut butter-oat mixture and provided with fibrefill for bedding. Traps were dug down to the ground surface and were covered with cardboard lids. They were set during the day and checked the following morning. Each transect was trapped for four consecutive nights during each winter period. Date and location of capture, sex, species, weight and reproductive condition were noted and each animal was tagged with a numbered ear-tag and subsequently checked for recapture status.

Population size was estimated by the program CAPTURE where a closed population was assumed (Otis et al. 1978). Movements and distribution of small mammals were estimated by using range length, the measure of the distance between the most widely separated capture points (DeBlase and Martin 1981). Distribution of animals in an area were categorized as random, uniform or clumped using an index of dispersion value (Morisita 1962). The analysis of variance and general linear models procedures were used to test for statistical significance (Box et al. 1978).

RESULTS AND DISCUSSION

Trapping over the winter (November-April) resulted in a total capture of 163 small mammals, which consisted of 157 *Peromyscus maniculatus* and 6 *Sorex spp.* (Table 1). Therefore, species diversity and abundance were both very low. *Microtus* species were probably present, but scarce. Snow accumulations and average daily temperatures were below normal. Trap mortality was 3.8%, a low value considering the cold temperatures and high winds that prevailed. Trap mortality for shrews was 100%.

Small mammal capture rates, an indication of the relative abundance, declined from early to late winter from 3.78% to 0.87%. A capture success rate of about 10% or 11.1 mice/ha represent normal population densities for *Peromyscus* (Terman 1968). Population lows for *P. maniculatus* can remain for up to 3 years and capture success can be as low as 0.04% (Herman and Scott 1984). Declines were a result of natural mortality and the cessation of breeding during the winter. Survival rates for *Peromyscus* are often very low with many living for only one year (Schug et al. 1991). This is especially evident during winter when mortality can be as high as 26%/month (Beer and MacLeod 1966).

Index of dispersion values (values greater than one) indicated that population distribution of *Peromyscus* was clumped over the winter and quite localized. Distances travelled by individuals increased from a low of 250 m in early winter, to a high of 1000 m in late winter, with males travelling greater distances than females during the onset of breeding in late winter.

Vegetation height, litter depth, and percent grass cover was significantly greater ($p<0.05$) in coulee and roadside habitats than in uplands. Upland habitats exhibited the greatest amounts of club moss and lichen. The deepest snow cover occurred in mid-winter and was significantly greater ($p<0.05$) in linear habitats than in

Table 1. Total winter captures of *Peromyscus maniculatus* in three study areas (Grasslands, Border, Onefour) in three habitats (upland, coulee, roadside). Estimates of population size by the program CAPTURE are in parentheses.

Study Areas	Winter Session	Habitat Types			
		Upland	Coulee	Roadside	TOTAL
	Early	53 (56)	34 (50)	—	87 (106)
Grasslands	Mid	2 (4)	2 (4)	1 (1)	5 (9)
	Late	1 (1)	4 (4)	1 (1)	6 (6)
	TOTAL	56 (61)	40 (58)	2 (2)	98 (121)
	Early	24 (26)	10 (11)	—	34 (37)
Border	Mid	0	0	0	0
	Late	0	3 (5)	0	3 (5)
	TOTAL	24 (26)	13 (16)	0	37 (42)
	Early	0	0	2 (3)	2 (3)
Onefour	Mid	0	0	1 (1)	1 (1)
	Late	2 (2)	7 (9)	10 (11)	19 (22)
	TOTAL	2 (2)	7 (9)	13 (15)	22 (26)
	GRAND TOT.	82 (89)	60 (83)	15 (17)	157 (189)

uplands. In early winter when snow accumulations were minimal, *P. maniculatus* was more abundant in upland habitat with less vegetation. In late winter, however, it was more abundant in coulees and roadsides with more abundant vegetation where snow-free zones were more prevalent along southern exposed slopes. Consequently, *P. maniculatus* showed no apparent affinity to any particular habitat type and its distribution was more dependent on snow cover, which is supported by the fact that this species of mouse is the most wide spread in North America, is highly adaptable and is a habitat generalist (Whitaker et al. 1980).

Several inferences can be made from the results of this study. High winter mortality of small mammals, combined with the already low numbers during a winter more severe than the norm, probably limited swift fox survival. The scarcity of food results in larger territory size required for predators to ensure an adequate food supply (Prestrud 1992). Therefore, the swift fox must expend more energy for finding food, which increases its likelihood of being exposed to predators such as the coyote. These factors must be taken into account when considering reasons for the decline in swift fox numbers and the potential for their successful reestablishment in the Canadian prairies.

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EFFECT OF GRAZING ON PLANT SPECIES DIVERSITY OF GRASSLANDS IN SASKATCHEWAN

Y. Bai

Research Station, Agriculture and Agri-Food Canada, 3015 Ord Road, Kamloops, British Columbia V2B 8A9

Z. Abouguendia

Grazing and Pasture Technology Program, P.O. Box 4752, Regina, Saskatchewan S4P 3Y4

R.E. Redmann

Department of Crop Science and Plant Ecology, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan S7N 5A8

Abstract: The Northern Great Plains grasslands evolved under natural disturbances such as fire, drought and grazing. Since European settlement, fire has been minimized or eliminated and bison have been replaced by domesticated livestock. It is not clear, however, how grazing by livestock affects grassland ecosystem parameters such as species diversity and productivity. Therefore, eight sites in central and southern Saskatchewan were studied in 1997 to determine plant species diversity as affected by light, moderate and heavy grazing. These sites represent various grassland types across the Mixed Grassland, Moist Mixed Grassland and Aspen Parkland ecoregions. Generally, moderate grazing tended to increase species richness, evenness and the Shannon's diversity index. The average number of species ranged from 12 to 27 per plot. The cumulative number of species increased rapidly in the first 2 m^2 sampled, and fewer species were added after 4 m^2. It was enhanced by moderate grazing, but reduced by light grazing. Heavy grazing may reduce, enhance or have no effect on the cumulative number of species. While heavy grazing reduced the biomass of grasses and favoured that of forbs, moderate grazing had little effect on either group; light grazing tended to reduce the biomass of forbs. Standing dead materials and litter tended to be reduced by all grazing treatments. The eight sites and the grazed and ungrazed subsites may be separated by the TWINSPAN (Two-way Indicator Species Analysis) procedure.

INTRODUCTION

Many wildlife lands in Saskatchewan receive no domestic grazing with the assumption that protecting native prairies from grazing is necessary to maintain wildlife habitat in healthy condition. Recent studies indicate that grazed lands can actually be healthier, produce more forage and have less standing dead materials than rangelands in exclosures (Shuman from Stelljes and Senft 1994). Rangelands in good ecological condition support more wildlife than those in excellent condition because of the lack of diversity in plant species and structure in the latter (Smith et al. 1996). Over the last several decades, applications of grazing research by ranchers and land managers have resulted in improved ecological condition of rangelands in North America (Heitschmidt from Stelljes and Senft 1994).

The structure and functioning of grassland ecosystems are closely related to the biodiversity components of these systems (Archer and Smeins 1991, Biodiversity Science Assessment Team 1994, Tilman and Downing 1994). Ungulate grazing is an important process in many ecosystems (West 1993). The Northern Great Plains grasslands evolved under natural disturbances such as fire, drought and grazing. Since European settlement, fire has been minimized or eliminated, and bison have been replaced by domestic livestock, mainly cattle. Plant species diversity can increase or decrease as a result of grazing (Huntly 1991). Improper utilization of rangelands by over-grazing can reduce cover and diversity of native plant species (Brady et al. 1989, Cooperrider 1991, Cottam and Evans 1945, Gardner 1950, Reynolds and Trost 1980, Rummell 1951, Szaro and Pase 1983, Winegar 1977). On the other hand, it has been predicted from theoretical models that moderate grazing may enhance species diversity compared to ungrazed lands (Milchunas et al. 1988). However, factors influencing biodiversity, including grazing, are incompletely understood (West 1993). This is particularly true for the native prairies in Saskatchewan.

Maintaining species diversity should become a desired objective of land managers (Fulbright 1996) because of the ecological, social and cultural values of grasslands, and because a diverse plant community is more resistant to disturbances (McNaughton 1985, Tilman and Downing 1994). Information about the impact of grazing on plant species diversity is needed by wildlife land managers and others when considering grazing as part of their management planning. Therefore, a study was conducted in 1997 with the following objectives: (1) to compare plant diversity and productivity of protected grasslands with those under light, moderate or heavy grazing, and (2) to evaluate changes in sward structure, plant and litter cover and vegetation layering under grazing, and their relations to plant diversity and productivity.

MATERIALS AND METHODS

Site Selection

Eight sites in Southern Saskatchewan were selected in June 1997 based on their geographical locations, plant community types, and land use history and practices (Table 1). One of the eight sites was located in the Aspen Parkland Ecoregion, one in the Moist Mixed Grassland Ecoregion, while the remaining six sites were in the Mixed Grassland Ecoregion. Within each site, an ungrazed sub-site was identified; the grazed sub-sites ranged from light to moderate, or heavy utilization, depending on sites. The ungrazed sub-sites were protected for 5 to over 30 years, depending on sites. The dominant species of each sub-site listed in Table 1 were determined based on results from the current study.

Four 8 x 8 m plots were randomly selected in protected and grazed areas at each site. A cage was arranged near each plot in the grazed area in late June before grazing occurred for productivity assessment. All plots were located on level upland to avoid variations caused by slope and/or aspect. Plant communities dominated by shrubs were avoided in sites with more than one community type.

Field Sampling and Data Collection

Field sampling was conducted in July and August 1997. Eight 0.5 x 0.5 m quadrats were randomly placed in each plot and the percent cover for each vascular species was visually estimated. Species in the genus of *Carex* were pooled as *Carex* sp. except *C. stenophylla* Wahl ssp. *eleocharis* (Bailey) Hulten (low sedge). The 8 x 8 m plot was then divided into sub-units and the number of new species occurring in the cumulative 2, 4, 8, 16, 32 and 64 m^2 was recorded.

Live forbs and grasses, standing dead materials and litter were clipped and hand-raked from 1 x 1 m quadrats in each plot. Litter was defined as any dead plant materials laying on the soil surface. These materials were oven-dried at 80° C for 48 hours and weighed.

Data Analysis

Mean vegetation cover of each species was calculated for each plot. Species richness, evenness, and diversity index (Shannon's Diversity Index) of each plot were calculated using PC-ORD (McCune and Mefford 1995). Mean cover was used in multivariate analysis with each plot being treated as an individual unit. Species occurring in less than 5% of the plots were eliminated and data were relativized by the overall maximum value before TWINSPAN (Two-way Indicator Species Analysis) for the classification of plots and sites. The relationship between cumulative number of species and sampling area were plotted into a species-area-curve to demonstrate the effect of grazing on species accumulation over the area. Data on productivity, species richness, species evenness, and species diversity index were analysed with ANOVA to detect the effect of grazing treatment.

RESULTS AND DISCUSSION

Effect of Grazing on Species Diversity

Species richness averaged from 7.8 to 20.8 per quadrat, and the overall averages were 14.2 and 15.6 for ungrazed and grazed sub-sites, respectively (Table 2). The effect of grazing on species richness was not statistically significant. Trends differed among sites: moderate grazing resulted in higher species richness at Grasslands National Park (GNP), Glenavon, and Arena; light grazing reduced species richness at Matador and Estevan. Heavy grazing either enhanced (Parkbeg and Chaplin) or reduced (Kerr) species richness. At Glenavon, species richness was enhanced in moderately grazed plots, then reduced in heavily grazed plots, to a level still higher than ungrazed plots.

Only one site exhibited significant effect of grazing on species evenness (Chaplin) (Table 2). Generally, grazing reduced the influence of dominant species and increased the evenness of grasslands except at Estevan (light grazing). The overall average of Shannon's diversity

Table 1. Site descriptions.

Site and grazing sub-site	Location	Ecoregion[1]	Dominant species[2]	Utilization
GNP and Dixon	Tp2R10W3	Mixed grassland		
Ungrazed			AGRDAS-KOEGRA-STICOM	Protected for about 5 yrs
Grazed (moderate)			AGRDAS-STICOM-KOEGRA	Summer grazing (June-Sept.)
Matador	Tp20-R13W3	Mixed grassland		
Ungrazed			AGRDAS-KOEGRA-EURLAN	Protected over 30 yrs
Grazed (light)			AGRDAS-KOEGRA-AGRSMI	No or light grazing (July-Sept.) in the last 3 yrs
Glenavon	Sec27Tp13R8W3	Aspen parkland (moss phlox).		
Ungrazed			FESHAL-POAPRA-STICUR	Protected for 6 yrs
Grazed (moderate)			POAPRA-FESHAL-STICUR	Late summer (July-Sept.) grazing
Grazed (light)			AGRSMI-POAPRA-STICUR	Late summer (July-Sept.) grazing
Estevan	Tp2R5W3	Moist mixed grassland		
Ungrazed			CALLON-STICUR-CARSP	Protected for over 10 yrs
Grazed (light)			STICUR-POAPRA-AGRDAS	Summer grazing (July-Sept.)
Parkbeg	S1/2Sec23Tp18R3W3m	Mixed grassland		
Ungrazed			STICOM-AGRDAS-KOEGRA	Protected for 7 yrs
Grazed (heavy)			STICOM-AGRDAS-KOEGRA	Summer grazing (June-Aug.)
Arena	Sec7Tp5R23W3	Mixed grassland		
Ungrazed			AGRDAS-STICOM-ARTFRI	Protected for 6 yrs
Grazed (moderate)			AGRDAS-STICOM-STICUR	Late summer grazing (Aug-Sept.)
Chaplin	NWSec27Tp17R4W3	Mixed grassland		
Ungrazed			STICUR-STICOM-AGRDAS	Protected for 15 yrs
Grazed (heavy)			KOEGRA-STICOM-STICUR	Late summer grazing (Aug-Sept.)
Kerr	SWSec15Tp14R28W2	Mixed grassland		
Ungrazed			AGRDAS-ARTFRI-BOUGRA	Protected for 7 yrs
Grazed (heavy)			PHLHOO-ARTFRI-KOEGRA	Late summer grazing (Aug-Sept.)

[1] Based on Padbury and Acton 1994.

[2] Based on results from the current study. AGRDAS = *Agropyron dasystachyum* (northern wheatgrass), KOEGRA = *Koeleria gracilis* (June grass), STICOM = *Stipa comata* (needle-and-thread), EURLAN = *Eurotia lanata* (winter fat), AGRSMI = *Agropyron smithii* (western wheatgrass), FESHAL = *Festuca hallii* (plains rough fescue), POAPRA = *Poa pratensis* (Kentucky bluegrass), STICUR = *Stipa spartea* var. *curtiseta* (western porcupine grass), CALLON = *Calamovilfa longifolia* (sand grass), CARSP = *Carex* sp. (sedge), ARTFRI = *Artemisia frigida* (pasture sage), BOUGRA = *Bouteloua gracilis* (blue grama), PHLHOO = *Phlox hoodii*

Table 2. Species richness, evenness and the Shannon's diversity index of plant communities in the eight sites. Numbers are means ± SE of four replications.

Site	Species richness	Species Evenness	Diversity index
GNP and Dixon			
Ungrazed	11.8 ±0.9	0.72 ±0.03	1.75 ±0.07*
Grazed (moderate)	15.8 ±1.7	0.78 ±0.02	2.12 ±0.03
Matador			
Ungrazed	17.0 ±1.1	0.64 ±0.02	1.81 ±0.08
Grazed (light)	14.8 ±0.9	0.66 ±0.02	1.78 ±0.08
Glenavon			
Ungrazed	15.5 ±2.1	0.58 ±0.08	1.56 ±0.26
Grazed (moderate)	20.8 ±2.6	0.69 ±0.05	2.09 ±0.22
Grazed (heavy)	17.8 ±1.6	0.76 ±0.06	2.19 ±0.23
Estevan			
Ungrazed	18.8 ±0.9	0.64 ±0.02	1.87 ±0.07
Grazed (light)	17.3 ±1.3	0.61 ±0.02	1.73 ±0.10
Parkbeg			
Ungrazed	7.8 ±1.3	0.61 ±0.07	1.23 ±0.21
Grazed (heavy)	10.0 ±1.3	0.66 ±0.03	1.51 ±0.05
Arena			
Ungrazed	11.0 ±0.9	0.73 ±0.06	1.76 ±0.18
Grazed (moderate)	11.8 ±0.9	0.76 ±0.02	1.85 ±0.05
Chaplin			
Ungrazed	14.3 ±0.9	0.56 ±0.05*	1.50 ±0.15*
Grazed (heavy)	15.8 ±1.7	0.76 ±0.01	2.09 ±0.10
Kerr			
Ungrazed	17.0 ±2.0	0.72 ±0.02	2.03 ±0.10
Grazed (heavy)	16.3 ±1.3	0.78 ±0.02	2.17 ±0.10
MEAN			
Ungrazed (n=8)	14.2	0.65	1.69
Grazed (n=9)	15.6	0.75	1.95

*Indicates a significant difference between ungrazed and grazed plots ($P \leq 0.05$)

index was 1.69 and 1.95 for ungrazed and grazed subsites, respectively. The Shannon's diversity index was statistically higher in grazed plots than ungrazed plots at Grasslands National Park (moderate grazing) and Chaplin (heavy grazing). For other sites, there was a trend that light grazing reduced diversity index, while moderate and heavy grazing increased it. A higher species richness and diversity of grazed lands compared to ungrazed has been reported in several grassland types, such as meadow communities in Oregon (Green and Kauffman 1995), tallgrass prairie (Collins 1987, Hartnett et al. 1996), and African grasslands (Smart et al. 1985) due to greater microsite diversity generated by grazing. Variations in species richness and diversity index among the eight sites were expected because the effects of grazing on plant species diversity depends on grazing intensity, site history and climate (Milchunas et al. 1988). Plant species diversity can also be related to range conditions (Groskorth 1998). In the next stage of this study we will estimate range conditions of the eight sites based on biomass component data and relate them to species diversity.

Species-area Curves

At all sites, cumulative number of species increased rapidly in the first 2 m^2 (the total area of 8 quadrats), and fewer species were added after 4 m^2 (Figure 1). The mean number of species ranged from 12 to 27 per quadrat. Light grazing tended to reduce the cumulative species number (Matador and Estevan), while moderate

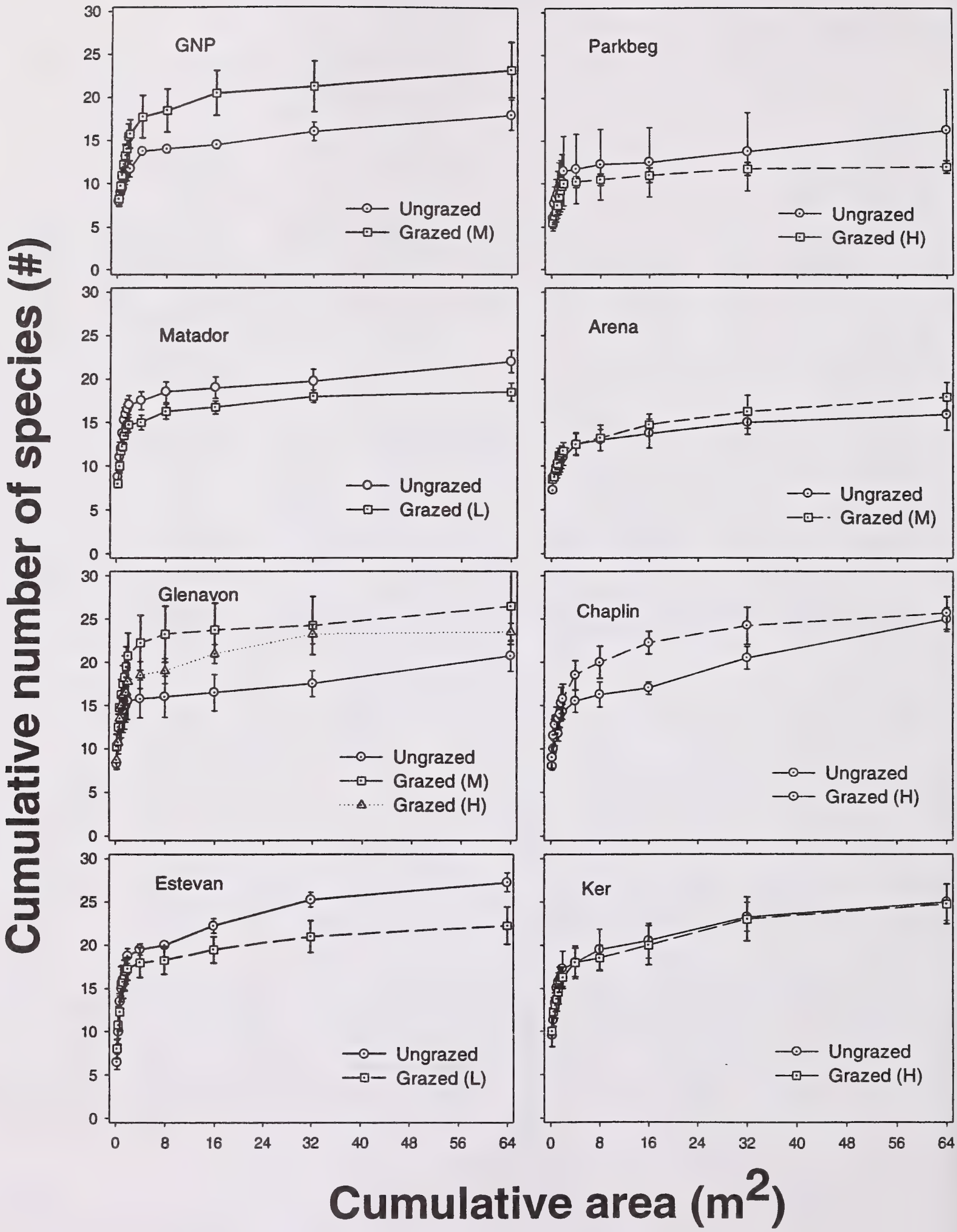

Figure 1. Species-area curves for plots from the eight sites. Numbers are means ± SE of four replications. L: light; M: moderate; H: heavy.

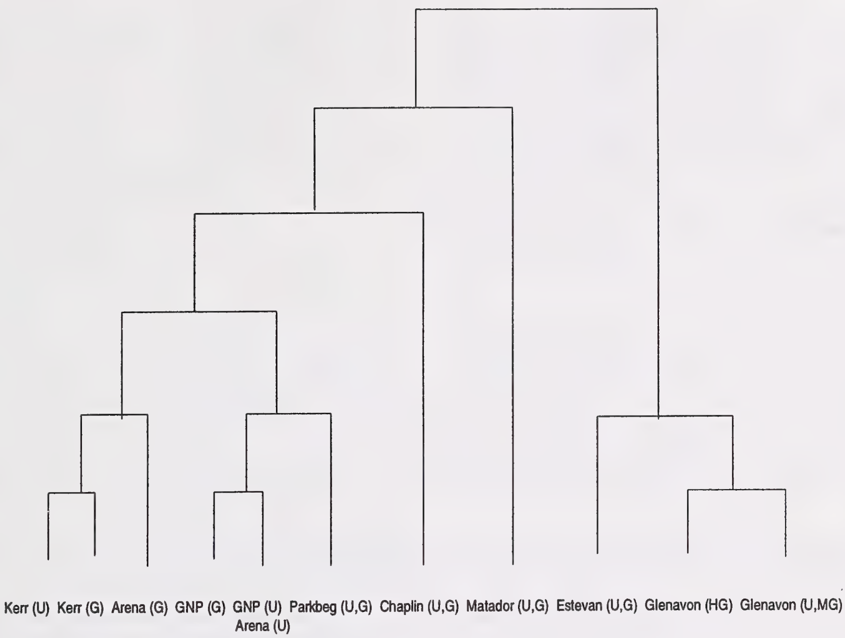

Figure 2. Classification of sites and sub-sites based on TWINSPAN output. U: ungrazed; G: grazed; HG: heavily grazed; MG: moderately grazed.

grazing tended to enhance it (Grassland National Park and Arena). Heavy grazing may reduce (Parkbeg), enhance (Chaplin) or have no effect on cumulative species number (Kerr). In Glenavon, the cumulative species number was enhanced by moderate grazing, then reduced by heavy grazing at a level still higher than ungrazed plots. A previous study also indicates a greater effect of grazing on species richness with increasing sampling area in the species-area curves in the Tallgrass prairie (Hartnett et al. 1996).

Classification of Plant Communities

Plots in the eight sites were placed into 12 groups of 6 levels by TWINSPAN, based on species composition and cover (Figure 2). Generally, the geographic location of sites was more important than grazing treatment in determining the plant community composition.

Glenavon and Estevan sites were separated from the rest by their high cover of Kentucky blue grass (*Poa pratensis* L.), purple milkvetch (*Astragalus danicus* Retz.) and western porcupine grass (*Stipa spartea* Trin. var. *curtiseta* Hitchc.) and their low cover of low sedge (*Carex stenophylla* Wahl spp. *eleocharis* (Bailey) Hulten) and June grass (*Koeleria gracilis* Pers) (Figure 2) . Matador differed from Parkbeg, Chaplin, Arena and Kerr by its high cover of yarrow (*Achillea millifolium* L.), but species composition and cover were similar between ungrazed and lightly grazed plots in Matador (even though green needle grass (*Stipa viridula* Trin.) tended to increase and June grass tended to decrease after grazing, Table 1). Glenavon was separated from Estevan by its higher cover of plains rough fescue (*Festuca hallii* (Varsey) Piper) and green needle grass typical of the black soil zone and lower sand reed grass (*Calamovilfa longifolia* (Hook.) Scribn.) and dotted blazing star (*Liatris punctata* Hook.).

Chaplin had lower cover of crocus anemone (*Anemone patens* L.), western porcupine grass, sedges (*Carex*) (other than low sedge), and Hooker's oat grass (*Helictotrichon hookeri* (Scribn.) Henr.), but higher June grass, than Parkbeg, GNP, Arena and Kerr (Figure 2). Heavily grazed Glenavon plots had less plains rough fescue than ungrazed and moderately grazed plots, and western wheatgrass (*Agropyron smithii* Rydb.) also increased after heavy grazing (Table 1).

Parkbeg, GNP and ungrazed Arena plots has higher cover of prairie muhly (*Muhlenbergia cuspidata* (Torr.) Rydb.) and lower moss phlox (*Phlox hoodii* Richardson) than Kerr and moderately grazed Arena plots. Parkbeg was again separated from GNP and ungrazed Arena plots by its higher cover of June grass and lower fringed sage (*Artemisia frigida* Willd.), northern wheatgrass (*Agropyron dasystachyum* (Hook.) Scribn.) and moss phlox (Figure 2). There was no difference in species composition for grazed and ungrazed Parkbeg plots because of their poor species richness (Tables 1 and 2). The moderately grazed Arena plots had higher cover of northern wheatgrass and lower sedges (*Carex* spp.) (other than low sedge), and spiny iron plants (*Haplopappus spinulosus* (Pursh) DC).

Moderately grazed GNP plots had less cover of prairie white aster (*Aster falcatus* Lindl.) than ungrazed GNP and Arena plots (Figure 2). Ungrazed Kerr plots had less skeletonweed (*Lygodesmia juncea* (Pursch) D.Don), but higher northern wheatgrass, and moss phlox became dominant after heavy grazing (Table 1).

Herbivores select certain species for grazing, and the vulnerability of plants to grazing also varies (Szaro 1989). In many rangelands the cumulative effect of long-term grazing is to keep succession in early stages (Longhurst et al. 1982). Savory (1988) suggests that intensive time-controlled, short-duration, planned-rotation grazing will shift rangeland vegetation to more successionally advanced and desirable species. Because grazing is part of the natural disturbances in the grasslands, the removal of it can destabilize some ecosystems (West 1993).

Effect of Grazing on Productivity

Heavy grazing reduced the biomass of grasses (Glenavon, Chaplin and Kerr), and favoured that of forbs (Table 3). Previous studies also show that dicotyledonous species are favoured by grazing, which may result in sward diversification (Ten Harkel and Van

Table 3. Biomass (g m^{-2}) of live vegetation, standing dead materials and litter in the eight sites. Numbers are means ± SE of four replications.

Site	Grass	Forb	Standing dead	Litter
GNP and Dixon				
Ungrazed	60.9 ±2.7*	29.6 ±5.9	17.4 ±1.2*	27.4 ±1.2
Grazed (moderate)	30.0 ±2.5	44.7 ±12.7	3.3 ±0.8	28.0 ±10.9
Matador				
Ungrazed	200.9 ±30.8	54.3 ±3.5*	101.3 ±31.4	139.4 ±20.6
Grazed (light)	167.3 ±17.0	31.9 ±4.6	66.3 ±6.7	102.4 ±18.6
Glenavon				
Ungrazed	233.8 ±12.8*	25.9 ±9.0	121.9 ±37.7*	612.9 ±78.6*
Grazed (moderate)	192.9 ±13.9	42.7 ±4.4	37.1 ±5.1	206.9 ±35.2
Grazed (heavy)	124.1 ±27.0	49.5 ±13.3	32.0 ±16.0	113.4 ±65.2
Estevan				
Ungrazed	151.2 ±5.6	22.0 ±12.3	92.1 ±8.4*	254.1 ±34.4
Grazed (light)	144.0 ±7.3	23.2 ±4.2	52.0 ±7.3	219.6 ±33.0
Parkbeg				
Ungrazed	51.8 ±4.6	8.8 ±2.8	45.8 ±5.7	104.6 ±14.1*
Grazed (heavy)	42.9 ±3.3	10.8 ±4.5	34.0 ±8.2	27.4 ±3.1
Arena				
Ungrazed	55.6 ±3.3	37.9 ±6.4	11.8 ±0.9*	30.8 ±1.9
Grazed (moderate)	61.5 ±4.6	32.2 ±8.0	7.4 ±0.7	31.7 ±4.5
Chaplin				
Ungrazed	111.4 ±10.3*	25.7 ±7.3	30.5 ±4.9*	94.4 ±25.6*
Grazed (heavy)	28.6 ±8.5	30.5 ±6.4	5.5 ±1.0	25.3 ±5.6
Kerr				
Ungrazed	99.6 ±13.6*	37.1 ±4.3*	29.7 ±8.0	110.0 ±18.3*
Grazed (heavy)	38.0 ±3.1	50.7 ±1.9	5.4 ±2.4	11.9 ±2.2

*Indicates a significant difference between ungrazed and grazed plots ($P \leq 0.05$)

der Meulen 1996, Watt et al. 1996). Moderate grazing may reduce (Grasslands National Park) or have no influence on grass productivity (Glenavon and Arena), while its effect on forbs was not significant. Light grazing did not affect grass productivity, but reduced forbs in one site (Matador). The biomass of standing dead materials and litter also tended to be reduced by grazing.

CONCLUSION

Light grazing has little effect on the species diversity of grasslands. As the degree of grazing increases, the species diversity tends to increase first and then decrease after certain point, depending on sites. More species accumulated as the sampling area increased in moderately grazed plots than ungrazed ones. The effect of grazing on plant communities was also exhibited in species composition. Grazing tends to reduce the productivity of grasses and enhance that of forbs. The biomass of standing dead materials and litter was also reduced by grazing. The research reported here has direct application to the management of grassland for purposes of protecting plant diversity, and results indicate that there is a potential for both habitat environmental enhancement and economic benefits as a result of incorporating grazing in land management. However, this study deals only with vegetation and soil surface components. It would be highly desirable to consider other ecosystem components such as insects, rodents and birds. Also, there is a need for a wildlife biologist to provide an interpretation of the vegetation study findings in relation to wildlife needs for food and cover.

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COMPETITIVE HIERARCHIES AMONG NATIVE GRASSES IN EASTERN CANADIAN PRAIRIE

D. Baluta and N.C. Kenkel

Quantitative Plant Ecology Laboratory, Department of Botany, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Abstract: A replicated diallel field experiment was undertaken to examine interspecific competition among 12 native grass species used in prairie restoration programs in western Canada. The objective of the study was to determine the magnitude and direction of the competitive hierarchy among the 12 grasses after two seasons of growth (1996-1997) in southern Manitoba. Above-ground biomass was harvested in the fall of 1997, and used to calculate pairwise relative yield and aggressivity values. Analysis of the binary aggressivity matrix revealed a completely transitive competitive hierarchy that included all 12 species. This hierarchy was related to two important plant functional traits, above-ground productivity and photosynthetic pathway (C3 vs. C4). Our results indicate that more productive species are more competitive than less productive ones, and that cool-season (C3) species are more competitive than warm-season (C4) ones. However, we recognize that our results may not hold true in all North American grasslands. We propose a conceptual model for predicting competitive hierarchies that is based on soil resource supply rates and the number of growing-degree days. The model proposes that cool-season grasses are favoured in northern grasslands and that the higher soil resource supply rates characteristic of eastern prairie favour tall-statured, more productive species.

INTRODUCTION

A common objective of restoration ecology is to establish and perpetuate biological diversity in the landscape (Jacobsen et al. 1994). In the restoration of Canadian prairie grasslands, establishing and maintaining a diverse array of native species, even in the short term, has proven to be a challenge (Morgan et al. 1995). It has been hypothesized that interspecific interactions occurring during the grassland establishment phase may lead to the exclusion of comparatively weak competitors, thereby reducing biodiversity. If interspecific competition is hierarchical and strongly asymmetric, the maintenance of high species diversity will be compromised, especially if natural disturbances such as fire and grazing are suppressed (Collins and Barber 1985, Keddy 1990). An understanding of competitive interactions is therefore critical to the success of grassland restoration programs, particularly when the objective is to promote and maintain a diverse assemblage of native grasses.

In this study, we use a field experiment to examine interspecific competitive interactions among 12 native grass species in southern Manitoba. The objective of the study is to determine the magnitude and direction of an established competitive hierarchy among the 12 grass species after two years of growth. In addition, we outline the plant functional traits that appear to confer a competitive advantage and describe a conceptual model to predict changes in the direction of competitive hierarchies across the North American prairie.

STUDY AREA

Our experiment was undertaken at the University of Manitoba Plant Science Research Fields at Winnipeg, Manitoba (49º 54'N, 97º 14'W). The experiment was established in May 1996 and harvested in September 1997. Long-term climatic means over the growing season (May-August) indicate a daily maximum temperature of 22.8º C and a mean monthly precipitation of 70 mm. From May-August 1996, the mean monthly precipitation averaged 78.6 mm and the daily maximum temperatures averaged 23.9º C. The soil is a slightly basic (pH = 7.6) cumulic regosol with a silty-clay texture. Total available nitrogen in the rooting zone (0-15 cm) is 2.63 g kg^{-1}.

MATERIALS AND METHODS

Experimental Design

Several approaches are available to determine the relative competitive abilities of a set of plant species (Keddy 1989). A powerful and commonly used approach is the diallel competition experiment (Wilson and Keddy 1986). In a diallel experiment, the *n* species

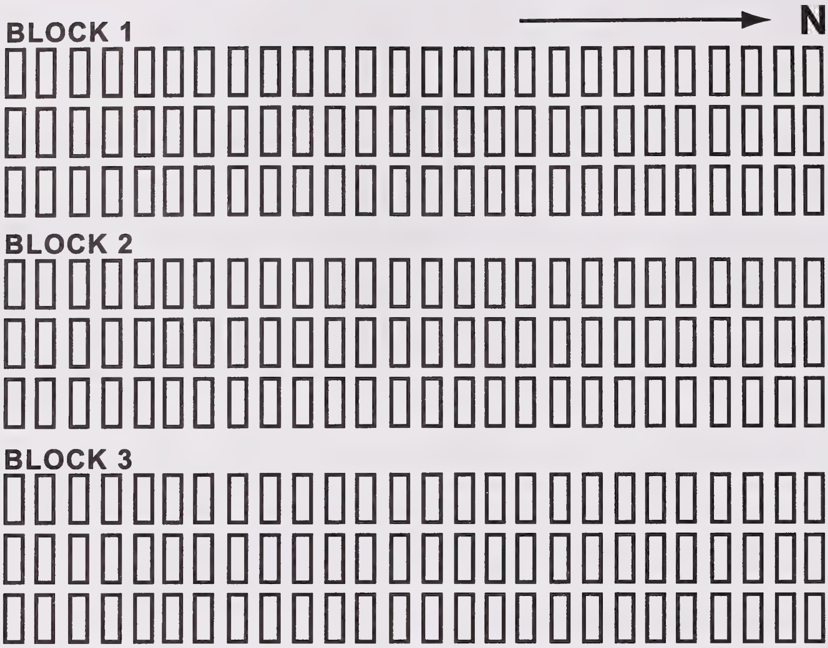

Figure 1. Layout of the 234 plots used in the diallel competition experiment. Plot size = 1.5 m x 3.5 m. Study area = 80 m x 47 m.

of interest are grown in monoculture and all possible pairwise combinations, giving a total of $n(n-1)/2$ mixture plots and n monoculture plots in one replicate of the experiment. In our experiment there were 12 grass species and three replicates, for a total of 3(12+66) = 234 plots established in a randomized block design (Figure 1). The 1.5 x 3.5 m plots were separated by 1.5 m wide vegetation-free lanes.

Species Used and Sowing Method

The 12 native grass species used in this experiment are commonly utilized by Ducks Unlimited in their grassland restoration programs in the eastern Canadian prairie. These included six cool-season (C3) and six warm-season (C4) species (Table 1). The seeds were obtained from various commercial growers. Pure live seed (PLS) values were determined from independent seed testing laboratories using tetrazolium chloride tests for seed respiration, or actual germination tests under controlled conditions.

Seeds were sown on May 30, 1996 using a Fabro™ six-row disk-type seeder. The sowing rate was 17 PLS per square foot (183 PLS m^{-2}), with the rows set at ca. 20 cm apart. These values are similar to those used by Ducks Unlimited Canada in their grassland revegetation programs.

Plot Management

Prior to sowing, the field was treated with the glyphosate herbicide Roundup™ at a rate of 880 g ha^{-1} to rid the field of perennial weeds such as dandelion (*Taraxacum officinale*), Canada thistle (*Cirsium arvense*) and quack-grass (*Agropyron repens*). Soon after sowing, a number of annual and perennial weeds became established in the plots, including lamb's-quarters (*Chenopodium album*), barnyard grass (*Echinochloa crusgalli*), green foxtail (*Setaria viridis*), Canada thistle (*Cirsium arvense*), wild buckwheat (*Polygonum convolvulus*) and wild mustard (*Brassica kaber* var. *pinnatifida*). Non-graminoid weed species were eliminated using 20 g ha^{-1} of Refine Extra™, applied on June 13, 1996. Graminoid weeds and other species that appeared throughout the summer were successfully removed by hand-weeding, and by rotivating the lanes between the plots. During the second growing season (1997), hand weeding and rotivation were only necessary on two occasions.

Table 1. Grass species used in the experiment and their above-ground productivity (mean monoculture yields at harvest). Classification as C3 or C4 species follows Waller and Lewis (1979). Species nomenclature follows Kartesz (1994).

Species	Common Name	Aboveground Productivity (g m^{-2})
Cool-Season (C3)		
Elymus canadensis L.	Canada Wild Rye	3618.4
Elymus trachycaulus (Link) Gould *ex* Shinners	Slender Wheatgrass	2155.8
Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	Northern Wheatgrass	1192.4
Nassella viridula (Trin.) Barkworth	Green Needlegrass	1119.4
Pascopyrum smithii (Rydb.) A. Love	Western Wheatgrass	961.2
Stipa comata Trin. & Rupr.	Needle & Thread	20
Warm-Season (C4)		
Andropogon gerardii Vitman	Big Bluestem	2761
Panicum virgatum L.	Switchgrass	2184.6
Sorghastrum nutans (L.) Nash	Indiangrass	1425.6
Bouteloua curtipendula (Michx.) Torr.	Side-Oats Grama	1003.6
Schizachyrium scoparium (Michx.) Nash	Little Bluestem	819.2
Bouteloua gracilis (Willd. ex Kunth) Lag. *ex* Griffiths	Blue Grama	89.6

Harvest Method

Three seeded rows, each 1m in length, were harvested from near the center of each plot. Harvesting took place during the first two weeks of September 1997, after two full seasons of growth. Harvesting involved the removal of all above-ground plant material. This material was sorted by species and placed into paper bags. The biomass was then dried for approximately three weeks in a heated plant-drying shed. Once the material was thoroughly dried, it was massed to the nearest 0.1 g using a Mettler™ digital balance.

DATA ANALYSIS

Relative Yield and Aggressivity

Species yield values (mean aboveground biomass over the three replicates) were first log-transformed to achieve homoscedasticity. Relative yields (McGilchrist and Trenbath 1971), defined as the ratio of the yield of species *i* when grown with species *j* to its monoculture yield, were then determined:

$$X_{ij} = Yij / Yii \qquad [1]$$

Y_{ij} is the yield of species *i* when grown with species *j*, and Y_{ii} is its monoculture yield. A higher relative yield value is indicative of greater potential species competitive ability (e.g. Goldsmith 1978, Wilson and Keddy 1986, Mitchley and Grubb 1986). Performance of a given species relative to that of a neighbour species is quantified by the aggressivity index (McGilchrist and Trenbath 1971, Mitchley and Grubb 1986):

$$A_{ij} = 0.5\ (X_{ij} - X_{ji}) \qquad [2]$$

X_{ij} denotes the relative yield of the species of interest (the 'target' species *i*), and X_{ji} denotes the relative yield of its competitor (the 'neighbour' species *j*). Note that aggressivity measures are symmetric apart from a change in sign ($A_{ij} = -A_{ji}$). Positive values for A_{ij} indicate that the target species *i* is a stronger competitor than the neighbour species *j*. The greater the aggressivity value, the stronger the competitive asymmetry between the two species.

The transformation from yield to relative yield corrects for differences in plant size, while the transformation from relative yield to aggressivity is used to determine which of the two species is the stronger competitor.

Transitivity Analysis

The matrix of pairwise aggressivity values was transformed into binary form by recoding positive values as ones and negative values as zeroes. This binary matrix was then examined to find and summarize all the completely transitive competitive hierarchies, using the algorithm proposed by Shipley (1993). Consider three species *A*, *B* and *C*: if species *A* outcompetes species *B*, and species *B* outcompetes species *C*, a completely transitive path (*A B C*) is defined if and only if species *A* also outcompetes species *C*.

RESULTS

Aggressivity

The full matrix of pairwise aggressivity values is given in Table 2, and mean aggressivity values for the 12 target species (row averages of the aggressivity matrix) are summarized in Figure 2. Mean aggressivity is positively and significantly correlated with species monoculture yield (Pearson product-moment correlation $r = 0.753$, $p < 0.01$). Of the four most aggressive species, three are cool-season (C3) grasses (*E. trachycaulus*, *E. canadensis*, and *P. smithii*), whereas three of the four least aggressive species are warm-season (C4) grasses (*S. nutans*, *S. scoparius* and *B. gracilis*).

Transitivity Analysis

Analysis of the binary aggressivity matrix revealed a completely transitive competitive hierarchy that included all 12 species (Figure 3). The species ranking based on this hierarchy is correlated with both mean aggressivity (Spearman rank correlation $r_s = 0.923$, $p < 0.005$) and monoculture yield ($r_s = 0.615$, $p < 0.025$).

DISCUSSION

The 12-species transitive competitive hierarchy found in our experiment is a reflection of two important plant functional traits, monoculture yield (above-ground productivity) and nature of the photosynthetic pathway (warm-season vs. cool-season). Our results indicate that highly productive species tend to be more competitive than less productive ones, and that warm-season species are generally less competitive than cool-season ones. In our experiment, the weakest competitors were warm-season species of low above-ground productivity.

Table 2. Matrix of species aggressivity values. Codes: Ag = *Andropogon gerardii*, Bc = *Bouteloua curtipendula*, Bg = *Bouteloua gracilis*, Ec = *Elymus canadensis*, El = *Elymus lanceolatus*, Et = *Elymus trachycaulus*, Nv = *Nassella viridula*, Ps = *Pascopyrum smithii*, Pv = *Panicum virgatum*, Sc = *Stipa comata*, Sn = *Sorghastrum nutans*, Ss = *Schizachyrium scoparium*.

	Et	Ec	Ps	Pv	Ag	El	Bc	Nv	Sn	Ss	Sc	Bg	Mean
Et	-	0.1	0.26	0.2	0.2	0.24	0.24	0.17	0.27	0.56	0.56	0.55	0.3
Ec	-0.1	-	0.15	0.15	0.11	0.1	0.26	0.1	0.21	0.29	0.3	0.56	0.19
Ps	-0.3	-0.2	-	0.1	0.1	0.1	0.18	0.17	0.22	0.41	0.56	0.57	0.17
Pv	-0.2	-0.2	0	-	0	0	0	0.1	0.28	0.14	0.55	0.42	0.1
Ag	-0.2	-0.1	0	0	-	0	0.1	0.1	0.24	0.31	0.55	0.1	0.1
El	-0.2	0	0	0	0	-	0.1	0.1	0.12	0.25	0.53	0.12	0.1
Bc	-0.2	-0.3	-0.2	0	0	0	-	0	0.1	0.12	0.55	0.53	0.1
Nv	-0.2	0	-0.2	0	0	0	0	-	0.1	0.11	0.57	0.1	0
Sn	-0.3	-0.2	-0.2	-0.3	-0.2	-0.1	0	0	-	0.1	-0.5	0.11	-0.2
Ss	-0.6	-0.3	-0.4	-0.1	-0.3	-0.3	-0.1	-0.1	0	-	-0.2	0	-0.2
Sc	-0.6	-0.3	-0.6	-0.6	-0.6	-0.5	-0.6	-0.6	0.54	0.18	-	0.46	-0.3
Bg	-0.6	-0.6	-0.6	-0.4	0	-0.1	-0.5	-0.1	-0.1	0	-0.5	-	-0.3

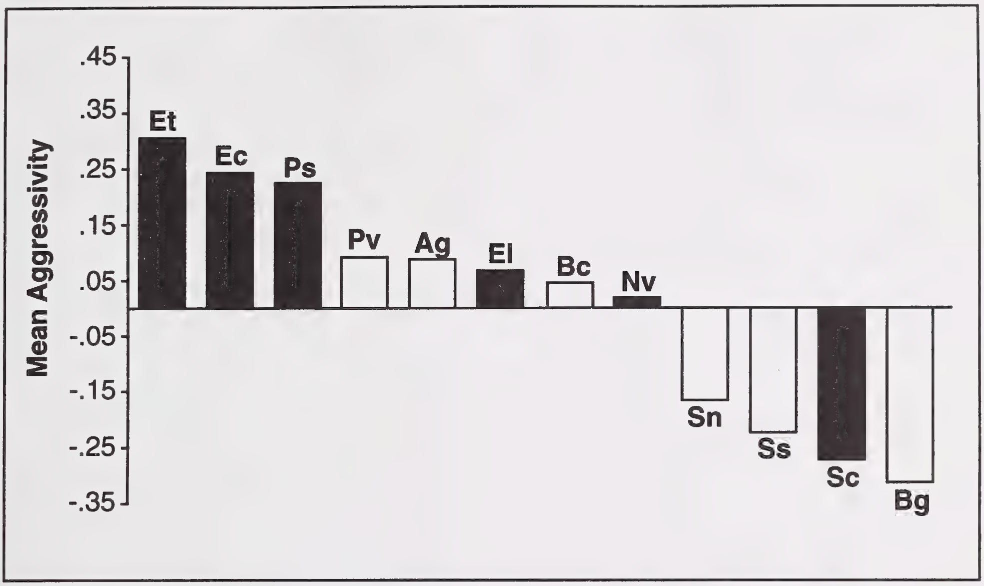

Figure 2. Mean aggressivity values of 12 native grasses grown at the Point in 1997. Means are calculated from all pair-wise possible combinations. Black bars represent C3 species; white bars represent C4 species. Codes: Ag = *Andropogon gerardii*, Bc = *Bouteloua curtipendula*, Bg = *Bouteloua gracilis*, Ec = *Elymus canadensis*, El = *Elymus lanceolatus*, Et = *Elymus trachycaulus*, Nv = *Nassella viridula*, Ps = *Pascopyrum smithii*, Pv = *Panicum virgatum*, Sc = *Stipa comata*, Sn = *Sorghastrum nutans*, Ss = *Schizachyrium scoparium*.

While we feel that our experimental results are broadly applicable to the mesic, clay-rich soils of the north-eastern prairie, we also recognize that it is unreasonable to assume that our competitive hierarchy will hold true in all North American grasslands. We hypothesize that the species competitive hierarchy at a given site is dependent on two factors: the relative availability of resources, and the number of growing-degree days.

Competition for light becomes increasingly important as soil resource (nutrients and/or water) supply rates increase (Wisheu and Keddy 1992). As the availability of soil resources increases, the taller and more highly productive species will preempt available light to the detriment and eventual exclusion of less productive species (Wedin and Tilman 1993). This shift from below-ground, symmetric competition to above-ground, asymmetric light competition as soil resource supply rates increase has been documented in a number of studies (e.g. Tilman 1984, Wedin and Tilman 1993, Wisheu and Keddy 1992, Huston and DeAngelis 1994, Keddy et al. 1997). In the North American prairie, soil resource

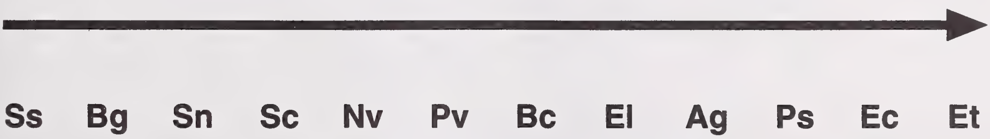

Figure 3. The completely transitive competitive hierarchy from the binary aggressivity matrix. Direction of arrow indicates increasing competitive ability. Codes: Ag = *Andropogon gerardii*, Bc = *Bouteloua curtipendula*, Bg = *Bouteloua gracilis*, Ec = *Elymus canadensis*, El = *Elymus lanceolatus*, Et = *Elymus trachycaulus*, Nv = *Nassella viridula*, Ps = *Pascopyrum smithii*, Pv = *Panicum virgatum*, Sc = *Stipa comata*, Sn = *Sorghastrum nutans*, Ss = *Schizachyrium scoparium*.

availability (water and nutrients) generally increases from west to east, reflecting a gradient of increasing annual precipitation (Bryson and Hare 1974). Tall, highly productive species are therefore favoured in the eastern 'tall-grass' prairie (Sala et al. 1988).

Relative competitive abilities of cool-season (C3) vs. warm-season (C4) grasses are dependent on the number of growing-degree days (Williams 1974, Ehleringer 1978, Zangerl and Bazzaz 1984). In the northern prairie, cooler summer temperatures and a shorter growing season favour grasses with the C3 photosynthetic pathway, due to their lower inherent energetic costs and higher quantum yields at lower temperatures (Ehleringer 1978). However, quantum yields for C3 species decrease to levels below those of C4 species as temperatures increase (Black 1971, Kemp and Williams 1980). It has been shown that shaded C4 plants (for example, those grown under a thick 'canopy' of C3 plants) have light saturation levels similar to those of C3 species, thereby reducing any inherent advantages of the C4 pathway (Williams and Markley 1973). Phenological niche differentiation occurs in grasslands where cool-season and warm-season grasses co-occur, with warm-season species delaying their period of maximum growth until later in the growing season when temperatures are higher (Kemp and Williams 1980). In more northern latitudes, the early onset of cooler autumn temperatures is unfavourable to warm-season species. Reduction in the relative competitive abilities of warm-season grasses in cooler climates is reflected in the decreased relative abundance of C4 grasses along a south-north gradient in the North American prairie (Epstein et al. 1997).

Dependence of species competitive abilities on both soil resource supply rates and number of growing-degree days suggests a conceptual model for predicting variation in competitive hierarchies in North American prairie (Figure 4). The environmental conditions that prevailed in our experiment (north-eastern prairie: adequate soil resource supply rates, and a short growing season) favour highly productive, cool-season grasses over short-statured, warm-season ones. Conversely, lower water and/or nutrient supply rates in the north-western prairie favour short-statured, cool-season grasses with well-developed root systems (Coupland 1950). Warm-season grasses are increasingly favoured as one moves south and the number of growing-degree days increases (Epstein et al. 1997). In southern prairies,

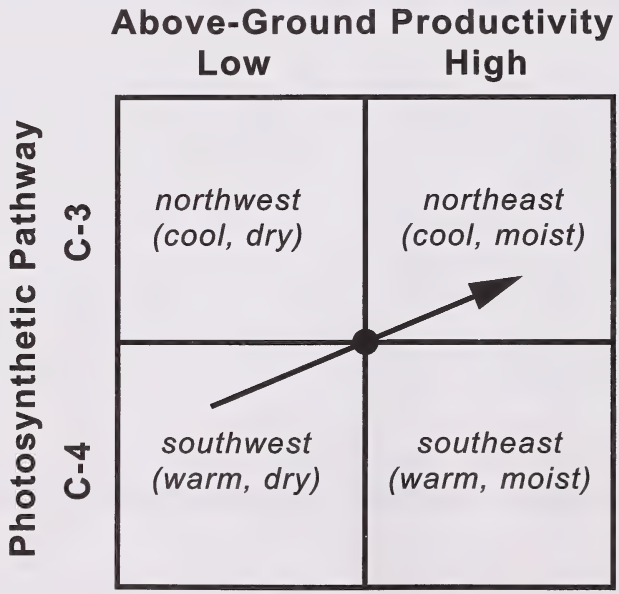

Figure 4. Model illustrating direction of competitive hierarchies based on species photosynthetic pathway and above-ground productivity. The pointer indicates the direction of the competitive hierarchy in our experiment, from weakest (low productivity C4 species) to strongest (high productivity C3 species) competitors. The arrow is directed toward the prevailing conditions at a given site. For example, in the southwestern Great Plains, the arrow would point in the opposite direction.

productive tall-statured warm-season grasses are generally favoured in eastern prairie, whereas short-statured, less productive warm-season grasses dominate the western prairie (Sala et al. 1988).

It should be noted that the large-scale geographic patterns illustrated in our model (Figure 4) could be substituted with finer-scale topographic features that affect resource supply rates. For example, the species competitive hierarchy that develops on relatively steep, north-facing slopes in south-eastern prairie is expected to be more typical of north-west prairie, due to lower levels of soil moisture and insolation. Studies on species distributions in native North American prairie generally support this hypothesis. In North Dakota, species of high above-ground productivity (*Elymus trachycaulus*, *Sorghastrum nutans*, *Andropogon gerardii*) dominate mesic habitats, whereas smaller-statured species such as *Bouteloua gracilis*, *Nassella viridula* and *Pascopyrum smithii* dominate less mesic sites (Dix and Smiens 1966). Similar results have been obtained in Saskatchewan prairie (Baines 1973, Hulett et al. 1966). In the mixed-grass prairie of Kansas, warm-season grasses dominate but vary in abundance along a soil moisture gradient (Albertson 1937). In xeric uplands, short-statured grasses such as *Buchloe dactyloides* and *Bouteloua gracilis* dominate, whereas medium-statured bunchgrasses such as *Aristida purpurea* and *Schizachyrium scoparium* are more abundant in less xeric sites. The most mesic sites are generally dominated by tall-statured, productive species such as *Andropogon gerardii*, *Bouteloua curtipendula*, and *Sporobolus drummondii*, as well as the cool-season grass *Pascopyrum smithii*.

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HAVE YOU CHECKED THE INGREDIENTS LIST?" BAKING THE ULTIMATE HABITAT PLAN

Michael T. Barr

Ducks Unlimited Canada, 5015 - 49th Street, Camrose, Alberta T4V 1N5

Abstract: In 1997, a pilot project was launched to demonstrate a method for program planners of the North American Waterfowl Management Plan to assess the incorporate biological diversity at the landscape level. The project was initiated in the Beaverhill Lake landscape of the Alberta Parkland eco-region because of its high importance to both waterfowl and other avian species. The relationship between breeding and migratory avian species occurrence and habitat type was inventoried for each of the nineteen habitat types. This information was used to identify specific habitat protection or management measures required by a range of migratory species in addition to waterfowl. This more ecosystem-based approach offers advantages of providing a more complete habitat program, wider public and scientific support and potential for funding partnerships.

Conserving biological diversity is an integral part of the North American Waterfowl Management Plan's (NAWMP) goal to restore healthy continental waterfowl populations. Although the biological diversity philosophy has been successfully adopted on a broad scale, significant challenges remain for implementation teams to translate this into action at the local level.

The "landscape" approach to planning and implementing a habitat program was adopted at the onset of the NAWMP in Prairie Canada. Landscapes, defined as distinct biogeographic areas often several hundred square miles in size, were intensively inventoried for wetland and upland habitats. Corresponding species groups of interest, in this case waterfowl, were also inventoried through surveys. From this foundation, waterfowl habitat programs were designed to address loss, degradation or threats to this habitat base. Needs of species other than waterfowl were deemed to be automatically incorporated with ongoing programs. Special needs by sensitive species were sometimes addressed.

Commitment to more fully address the needs of other species steadily expanded within the NAWMP. While recognizing the continued focus on wetland wildlife, potential existed to *proactively* pursue habitat programs for the full range of species contained in a landscape in a very efficient manner. This would result in a more comprehensive program attracting a greater base of both public and financial support. However, what are the "ingredients" and priorities in an expanded program? The challenges of information shortages on species occurrence (current and historical), regional or national status, endemicity and local species-habitat relationships discouraged preparation of broader landscape plans.

A pilot project was launched in an attempt to demonstrate a method for program planners of the NAWMP to incorporate biodiversity at the landscape level. During the 1997 field season, a study was undertaken in the Beaverhill Lake landscape to inventory as many breeding and migratory avian species as possible. This landscape, located within the Alberta Parkland, was chosen because of its prominence as a biologically diverse area and the presence of other partners willing to assist in this study. Environment Canada, the Beaverhill Bird Observatory (in cooperation with the Canadian Nature Federation) and Ducks Unlimited Canada under the NAWMP were all contributing partners. One research individual conducted surveys between April and November. Nineteen distinct habitat types were sampled throughout the landscape and the relationship between species occurrence and habitat type was observed. This current information will be combined with historical records of species occurrence by other agencies, groups and local naturalists. The final report will summarize the occurrence of all recorded avian species and their habitat relationships in the landscape (if known).

Armed with this detailed knowledge, planners will be able to build comprehensive conservation plans specific to this or other important landscapes. Habitat protection and management needs of all species, not simply wetland-based or waterfowl species, can be merged and addressed on an appropriate basis. The former assumption of automatically addressing other species needs, while often true, will be replaced by a more sophisticated information-based plan. Opportunities for new partnerships, such as demonstrated by this pilot project, will escalate as groups see potential to address their specific interest in a scientifically-based, low-cost manner. An advisory committee including all contributing partners could assist in the development and activation of this conservation strategy. The committee could be further strengthened through inviting representation by the local community.

Positive reviews of this pilot project will lead to completion of other key NAWMP landscapes in time. Conserving biological diversity as an integral part of the NAWMP will then be *fully* realized. Supporters of the NAWMP will take extra pride in having “baked” the ultimate habitat conservation plan.

PLANTWATCH: BIOMONITOR FOR CLIMATE CHANGE

Elisabeth Beaubien

Devonian Botanic Garden, University of Alberta, Edmonton, Alberta, T6G 2E1

Abstract: Spring plant phenology may be the most sensitive and observable indicator for climate change. Since spring flowering occurs in response to temperature, we should see a trend to earlier flowering with the western Canada trend to warmer winter and spring seasons. Central Alberta records show a trend to spring arriving about a week earlier over the last four decades. Early flowering years correlate with El Nino years and warmer Pacific ocean temperatures. The Alberta Wildflower Survey has researched bloom times for 15 plants since 1987, with the help of about 200 volunteer observers annually. Plantwatch (see internet homepage: http://www.biology.ualberta.ca/devonian.hp/pwatch.htm) now links students and adult observers in reporting via computer the flowering of 8 plant species found across Canada and much of the United States. This seasonality data is useful in "best-timing" predictions for agriculture and horticulture, forestry, health and wildlife management, and also in ground-truthing for satellite images.

WHY PHENOLOGY?

The seasonal timing of plant development (phenology), surveyed over many years, allows tracking of the biotic effects of climate change. Alberta dates of bloom for 15 spring-flowering wild plants have been gathered from about 200 volunteers annually since 1987 (Beaubien and Johnson 1994), and earlier: 1973-1982 (Bird 1983).

In temperate zones of the earth with distinct cold and warm seasons, temperature is the main driver in the first half of the year, controlling timing of plant life stages such as budburst, leaf out, and spring flowering of perennials. Photoperiod (day length) has a greater influence in the second half of the year, largely determining the timing of events such as fruit ripening, leaf colouring, and leaf fall. Because spring flowering of perennials in largely in response to accumulated temperature, warm winters and springs result in early flowering. An analysis of 60 years of Edmonton data shows a clear trend to earlier development in recent years, especially for the earliest bloomers, prairie crocus (*Anemone patens*) and aspen poplar (*Populus tremuloides*). Warm winter Pacific ocean temperatures are associated with early spring as well (Beaubien and Freeland 1997), and based on February 1998 ocean temperatures we predict the 1998 spring flowering index for Edmonton to be 12 days earlier than average. This index is an annual mean for first bloom dates of aspen poplar, saskatoon (*Amelanchier alnifolia*) and chokecherry (*Prunus virginiana*). All medium and strong El Nino events in the last 2 decades have been associated with early plant development in central Alberta (Beaubien unpublished).

Since 1987, the "Alberta Wildflower Survey" has researched flowering dates for 15 native plants via a 200-member volunteer network. These phenology data can be used in many ways:

- climate change: is there a trend to earlier spring flowering?
- biozonation: how do areas differ with respect to onset of growth?
- remote sensing: ground-truthing for satellite vegetation index imagery
- integrated pest management: predict optimal control times for insects
- medicine: pollen-warnings for those with allergies
- wildlife management: predictions for grizzly movements, or abundance of deer

PLANTWATCH

Launched in 1995, Plantwatch links students and other observers as the "eyes of science," tracking the green wave of spring moving north. Students develop scientific skills while observing springtime changes in plants and learning about biodiversity. Observers monitor flowering of up to eight plant species and report the bloom times over the Internet. Resulting maps are posted weekly to the Internet. Observer/teacher manuals illustrate flowering stages and describe the program and curriculum connections.

Plantwatch seeks observers internationally for lilac, and across North America to report flowering dates for these 8 key indicator plants.

1. common purple lilac: *Syringa vulgaris* (worldwide, common in gardens: a cultivar)

2. aspen poplar: *Populus tremuloides* (continent-wide)
3. prairie crocus: *Anemone patens*: (west: prairies, and north)
4. saskatoon, serviceberry: *Amelanchier* (continent-wide)
5. western trillium: *Trillium ovatum* (western forest)
6. white trillium: *Trillium grandiflorum:* (eastern deciduous forest)
7. purple saxifrage: *Saxifraga oppositifolia* (arctic, mountains)
8. alpine dryad: *Dryas octopetala* (mountains)
   arctic dryad: *Dryas integrifolia* (arctic)

This Plantwatch program (on line at http://www.biology.ualberta.ca/devonian.hp/pwatch.htm) can potentially attract many Canadian observers to report on the plant response to the current El Nino event. This event is predicted to bring warmer, dryer conditions to western Canada, and therefore plant and insect development could be considerably earlier than average this coming spring (1998).

Registration and data reporting are done electronically or by mail, and results with maps of the flowering progress are updated weekly on the Internet. While weather instruments are expensive, these indicator plants are widespread and act as biological measuring sticks of local climate. Benefits for observers include "hands-on" awareness of connections between the weather and development of plants (Beaubien 1996, 1997). Participants see their observations on maps and can track the green wave of spring. They have the opportunity to contribute their skills as "eyes of science" towards a better understanding of the plant responses to climate variability, and to see how their area is different.

PREDICTING THE "BEST TIME"

As growth of plants and insects in spring is keyed to temperature, development of species occurs in a consistent sequence and the timing of insect stages can be predicted from the timing of previous plant stages. Appearance of showy flowers is easy for the public to observe, easier than some simultaneous but hidden event such as the appearance of the 4th instar of a tiny grasshopper, or the hatch of ruffed grouse chicks. In any given year, the sequence of development of organisms is largely predictable. A study of 25 years of phenology data of the German Weather Service showed that correlations between times of occurrence of different spring events (e.g. first bloom of dandelion and first bloom of lilac) were highly correlated. This is also true for insects, so that the best predictor of when a particular insect will emerge can be the timing of bloom of a plant many days before.

For example, if saskatoon bushes are at full bloom in Edmonton on May 20, then lilacs will most likely reach full bloom June 3 and a major pest of saskatoon (woolly elm aphid: *Eriosoma americanum*) can be best controlled on June 17 (Beaubien and Fry in progress). Since the timing of early spring development can vary by 6 weeks between very early and late springs, Plantwatch can alert farmers to make appropriate decisions in each succeeding growing season. By treating an insect at its most vulnerable stage, farmers can save money and minimize their environmental impacts.

This knowledge was once common sense. When Samuel de Champlain landed at Cape Cod in 1605, he learned that the best time to plant corn was when the white oak leaves matched the size of the red squirrel's footprint. East coast residents would fish for shad depending on development times for shadbush (*Amelanchier*). Fishers say "Pickerel run when the cottonwood blooms and blows," and "Goldeye run when the wild roses bloom." Alberta fly fisherman Bob Scammell (in his book *The Phenological Fly*) notes that the emergence of the biggest mayfly in North America *Hexagenia limbata*, which drives large brown trout into a feeding frenzy, coincides with the flowering of the Brown-Eyed Susan: *Gaillardia aristata*. We have over 20 years of flowering times for this plant all over Alberta, so a predictive model could be developed!

Prairie Blackfoot hunters waited in spring to hunt bison bulls until Golden Bean (*Thermopsis rhombifolia*) flowered: at last the bulls, after the lean winter, had eaten enough green grass to be tasty! Cattlemen also use this bloom's appearance to indicate the time to put cattle on the range. Bill Hall (Pers. Comm.) showed in this thesis that the most important factor influencing the success of white-tail deer fawns was spring earliness. In years with early springs, more fawns were produced. Farmers often use natural indicators to select best times to plant. "Potatoes can be planted when leaves appear on aspen poplar." The timing of aspen bloom (which occurs a predictable interval before leafout) can vary by many weeks from a very early to very late spring, so adapting to the current season can mean much better harvests! Especially in years when spring comes early, (thanks again, El Nino), why waste precious growing time waiting to plant until the 24th of May?

LINKS TO INSECTS AND REMOTE SENSING

With insect specialist Dr. Dan Johnson of Lethbridge Research Station, Agriculture Canada, and with Dr. Mryka Hall-Beyer of the Department of Geography, University of Calgary, I am currently comparing plant data with insect data and satellite images, to see how well the data sets correlate. Growth can be predicted for beneficial soil insects using weather factors (Johnson and Wellington 1980). Models have been also developed to forecast rangeland pest grasshopper development and to use mapping in managing grasshopper control (Johnson 1993).

These plant and insect data can be correlated with remote sensing (satellite) data. As satellites see only the "tops of the plants," and from far above Alberta, interpretation of phenomena such as grasslands greening up much later than forests due to accumulated litter obscuring new growth, must be taken into account. While stratification of the Normalized Difference Vegetation Index (NDVI) data according to ecoregion is fairly advanced for the coterminous USA, it has not been undertaken for more northern areas with their particular problems. NDVI metrics that have proven useful elsewhere in characterizing plant phenology (Reed et al. 1994) are being calculated for Alberta. Developing this process model that moves from the on-the-ground plant and insect response to a "how it would look from space" perspective, will provide a vital tool towards an understanding of responses to climate variability (Cumming and Burton 1996, White et al 1997).

THE FUTURE

With Stan Orchard of the Amphibian Monitoring Network in Canada, I am working towards a daily "Nature Report" broadcast on television to track the seasonal progress of flowering, bird migration, caribou migration, bear emergence, and other seasonal events. Plantwatch participants will certainly enjoy seeing their contributed observations on nightly TV!

Tracking the biotic response to climate variability and change is important. Please join Plantwatch and share with us your spring discoveries: just pick a favourite crocus patch or lilac bush to report on! Or find a school class to encourage; as "eyes of science," they'll have fun tracking the green wave of spring!

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RARE PLANT SURVEY TECHNIQUES: A CRITIQUE

Diana Bizecki Robson

Nelson Dynes & Associates Inc., 242A Cardinal Crescent, Saskatoon, Saskatchewan, S7L 6H8

Abstract: The recent protection of rare plants under Saskatchewan's Wildlife Act has resulted in an increased demand for rare plant surveys. I described and critiqued three rare plant survey techniques according to the ability to detect rare plants, labour intensity required and documentation provided. The surveys I critiqued included the floristic survey, search image and habitat analysis techniques. The floristic survey technique was deemed to be the best due to extensive documentation and high rare plant detectability.

INTRODUCTION

In the spring of 1997 amendments were made to Saskatchewan's Wildlife Act. Under this Act, certain rare plants in the province will be legally protected. This legislation has resulted in an increased demand for rare plant surveys in Saskatchewan by various industries.

The objective of this research was to conduct and critique three rare plant survey techniques and determine which one was the best method to use over both large and small study areas.

FLORISTIC SURVEY TECHNIQUE

A floristic survey is the most detailed type of rare plant survey since all plants species encountered must be identified (Nelson 1987). The procedure is as follows:

- A botanist traverses the study area via meandering or linear transects;
- All plant species seen are identified and recorded on a data sheet;
- Once all unique habitats and plant communities have been visited and no additional species are being encountered, the survey is terminated.

Advantages of the Floristic Survey Technique

- The provision of survey data sheets enables clients, the public and the government to assess survey adequacy;
- This method forces the botanist to identify all plants encountered, decreasing the possibility that a rare plant will be misidentified or overlooked;
- If both a rare plant survey and floristic information are required for a project you can "kill two birds with one stone" by using this technique.

Disadvantages of the Floristic Survey Technique

- Depending on the botanist's familiarity with the local and rare vegetation, a considerable amount of post-field work may be required to identify unknown species;
- This technique is labour-intensive and time-consuming; therefore, it may not be the best method to use over very large areas.

SEARCH IMAGE TECHNIQUE

The search image technique appears to be the method used by most consulting companies in the prairies. This technique is a type of targeted search where specific rare plants are looked for. The procedure is as follows:

- Before going into the field, the botanist contacts an organization with a rare plant database;
- A list of rare species found within or immediately surrounding the study area is compiled using the rare plant database;
- When in the field, the botanist scans the entire study area, looking for rare plants on the rare plant database list;
- Any rare plant sightings are recorded.

Advantages of the Search Image Technique

- Very little post-field work identifying unknown plants is required;
- This method is less labour-intensive than the floristic survey technique over large areas.

Disadvantages of the Search Image Technique

- No documentation is provided to confirm that an adequate search was conducted;
- Information in rare plant databases is incomplete, as many areas have simply not been searched for rare plants. This means that a botanist may overlook

an unexpected rare plant using this technique, resulting in lower survey accuracy.

HABITAT ANALYSIS TECHNIQUE

The habitat analysis technique is another type of targeted search that involves surveying suspected rare plant habitats within the study area. The technique proceeds as follows:

- Before conducting the field work, a list of habitats (i.e. valleys, sand dunes, etc.) within the study area is compiled using available literature, maps and air photographs;
- Rare plant literature and database information are studied to determine which rare plants may grow in these habitats;
- The botanist visits the potential rare plant habitats, searches for the rare plants associated with each habitat and records any sightings.

Advantages of the Habitat Analysis Technique
- This technique is useful when detailed surveys are not needed;
- Habitat analysis is not labour-intensive because only those habitats with a high probability of containing rare plants are visited during the survey.

Disadvantages of the Habitat Analysis Technique
- No means to assess the adequacy of the survey is provided;
- As rare plants are not always predictable in where they occur, this technique may overlook the unpredictable species resulting in lower accuracy;
- This method is not intensive enough for surveys over small areas.

CONCLUSION

The floristic survey is the best technique for small developments like oil wells and mine sites. The chance of a rare plant being overlooked is low, because the botanist must identify all plants in the area. Post-field work identifying unknown plants can be reduced if the botanist is familiar with the local vegetation. Most importantly, a means is provided to assess the quality of the survey with this method.

A habitat analysis is useful for low-intensity surveys over large areas. The amount of detail a habitat analysis goes into will vary with the financial resources available.

Thus, the ideal rare plant survey technique depends on the size of the project area and the level of intensity that is required. In general, more intensive surveys are required when there will be a significant amount of disturbance to the site (i.e. soil excavation, heavy vehicle traffic, etc.). Low intensity surveys may be suitable for project and management planning for large tracts of land.

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GRASSLAND INSECTS AND BIRDS: THE IMPORTANCE OF INSECTS AS FOOD, AND CAREFUL CHOICE OF INSECT CONTROL METHODS

Yves Bousquet, Melissa Cammer, Kort Clayton, Eneida de Cruz, Douglas Forsyth, Bernard Hill, Dan Johnson, Chris Lomer, Pamela Martin, Pierre Mineau, Joe Schmutz, and Judit Smits

Abstract: Grassland insects serve as important food for grassland birds, and in turn certain grassland birds are significant predators affecting insect populations. We have conducted four studies to harmonize control or rangeland insects with the ecological wellbeing of grassland birds.

a) Ecotoxicological tests of registered insecticides used for grasshopper control on young ring-necked pheasants indicated significant differences in the degree of acetylcholine esterase inhibition and behavioral modification. In light of recent deaths of Swainson's hawks in Argentina during grasshopper control operations, we need to examine the ecotoxicology safety of registered products and cooperate internationally to ensure safety for migratory birds that use grassland insects as food.

b) Fungal diseases that kill insect pests are candidates for use as alternative control agents. In controlled experiments, we fed spores or grasshoppers that had been infected and killed by entomopathogenic fungi to ring-necked pheasants. Growth, survival and examination of tissues from key organs indicate no negative impacts.

c) Taxonomic examination of the diet of burrowing owls in Saskatchewan and Alberta indicated that they eat large numbers of rangeland insects. Over 300 pellets were collected, weighed, and separated to allow identification of the remains of food items. Grasshoppers (pest and non-pest species), ground beetles (predators), and carrion beetles (detrivores/decomposers) were common components.

d) Field experiments were conducted to determine the relative importance of grassland insects in the diets of grassland songbird nestlings (chestnut-collared longspurs), and experimentally assess the impact of removal of the food source during typical aerial application of insecticide for grasshopper control. Results indicated that allowing survival of as little as 5-10% of the initial insect densities provides food resources sufficient for successful survival and fledging of longspurs.

AUTUMN MIGRATION OF SASKATCHEWAN BURROWING OWLS

Kort M. Clayton

Department of Biology, University of Saskatchewan, 112 Science Place, Saskatoon, Saskatchewan, S7N 5E2

Karyn Scalise

Saskatchewan Environment and Resource Management, Room. 436, 3211 Albert Street, Regina, Saskatchewan, S4S 5W6

Abstract: Determination of the migratory route and wintering grounds of the Canadian prairie burrowing owl (*Speotyto cunicularia*) population remains a priority of the Burrowing Owl Recovery Team. This information could help direct future research to determine mortality factors during the non-breeding period. During September 1997 Saskatchewan Environment and Resource Management captured and radio-marked 13 owls from Moose Jaw, Saskatchewan. These owls were subsequently monitored from the ground to determine migratory departures. Diurnal aerial searches were conducted, using a Cessna 185 with strut-mounted Yagi antenna, to relocate migrant owls. A ground crew was also employed to confirm migratory locations, collect qualitative habitat information and monitor owls at migratory roosts. Mean (± SD) date of migratory departure for 12 owls was 4 Oct ± 7d. Aerial searches revealed five burrowing owl migratory roost locations. Three owls were located in southern Saskatchewan the day after departure from Moose Jaw. Two days later, two owls were located near Dickinson, North Dakota. In general, owls moved in a south-southeasterly direction, migrated at night, and did not necessarily fly every night. Nightly movements (N = 4) averaged 186 km (109-326 km). Linear distance from Moose Jaw to the furthest owl location near Dickinson was 452 km. Most owl roosts were badger excavations in grazed pastures.

INTRODUCTION

The burrowing owl (*Speotyto cunicularia*) occupies grasslands, deserts, and steppes from western Canada down throughout South America (Johnsgard 1988). These owls rely on burrows year round for both nesting and roosting. Abandoned burrows of badgers (*Taxidea taxus*), prairie dogs (*Cynomys* spp.), and ground squirrels (*Spermophilus* spp.) are commonly used. The burrowing owl is a generalist predator of small rodents, insects, birds, and herptiles (Gleason and Johnson 1985, Marti 1974, Plumpton and Lutz 1993, Silva et al. 1995, Thompson and Anderson 1988).

At the northern end of the burrowing owl's range in Canada, populations have declined and the range has retracted considerably over the past 30 years (Wellicome and Haug 1995). As a result, burrowing owls were listed as threatened in 1978 (Wedgwood 1978), and uplisted to endangered status in 1995 (Wellicome and Haug 1995) by the Committee on the Status of Endangered Wildlife in Canada.

Numerous studies have addressed burrowing owl foraging, diet, productivity and survival in Canada (Clayton 1997, DeSmet in press, Haug 1985, Haug and Oliphant 1990, Schmutz 1991, Wellicome et al. in press). Since 1992, Saskatchewan Environment and Resource Management has been installing predator proof nest boxes and providing supplemental food to a population of burrowing owls nesting on the Regina Plain. These measures have been shown to improve pre-fledging survival by reducing nest predation, starvation of juveniles, and siblicide among juveniles (Wellicome 1994, Wellicome et al. in press). Despite enhanced fledging success, this population continues to decline (35% from 1996 to 1997). This suggests that pre-fledging survival is not the most significant factor limiting the Saskatchewan burrowing owl population.

Radio-telemetry studies and subsequent demographic modeling of the Hanna, Alberta burrowing owl population suggest that mortality of both adults and juveniles during the post-fledging period comprises 68% of annual mortality (Clayton 1997). Post-fledging mortality of adults and juveniles on the Regina Plain, Saskatchewan is similar to that in Alberta (Clayton 1997). Hence, post-fledging mortality could contribute similarly to annual mortality of Saskatchewan owls.

Additional mortality undoubtedly occurs on fall and spring migrations and over the winter. Unfortunately, we know very little about what burrowing owls do or where they spend this six month non-breeding period. Banding efforts have not provided sufficient data to trace the migratory route or wintering grounds. As of 1995, 2996 burrowing owls had been banded in Canada and only 9 bands have been recovered off the breeding grounds (H. Trefry Pers. Comm.). Differences in recovery rates between U.S. and Canadian banded owls has led to speculation that Canadian owls might leapfrog the U.S. migrants and spend the winter in Mexico or Central America (James 1992).

Preliminary attempts have been made in Alberta and Saskatchewan to track burrowing owls on migration using aerial telemetry techniques (Clayton 1997). These efforts yielded some useful data on migration dates, departure times, and initial movements. Migratory departure from both study areas ranged from late September through mid-October: Hanna, Alberta, 2 Oct. ± 8d (mean ± SD), N = 18; Regina Plain, Saskatchewan, 6 Oct. ± 8d, N = 14. A few owls monitored during the evening in Alberta were detected leaving on migration about one hour after sunset: 12 Oct. 1995, 2000 hrs; 19 Oct. 1996, before 1930 hrs. One adult male was relocated the day following his nocturnal departure. This initial movement was 65.7 km, and on an azimuth of 187°. This owl did not continue migrating the next night. Monitoring was discontinued the following day.

Satellite telemetry is a very effective technique for monitoring the movements of animals over vast areas (Fuller et al. 1995, Schmutz et al. 1996). Unfortunately, the smallest commercially available satellite transmitters weigh ≈18-20 g (U. Banasch Pers. Comm.). With burrowing owls averaging 150 g, this exceeds the currently accepted weight restrictions for transmitter packages on birds (3-5% of body weight) (Caccamise and Hedin 1985, Samuel and Fuller 1996).

Radio-marked, migrating birds have been successfully tracked from aircraft during the day (Iverson et al. 1996, McClelland et al. 1996, Yarris et al. 1994). Aerial tracking is the best and most acceptable method available to follow migrating burrowing owls.

The main objective of this project was to evaluate the potential to follow migrating burrowing owls and to revise our techniques to maximize success. Our ultimate objective, discovering the wintering grounds of Saskatchewan burrowing owls, will be facilitated by any information we can gather on migratory strategies, e.g., timing, speed, movement frequency, or altitude.

METHODS

Local

Owls were captured by hand in artificial nest boxes, or trapped with noose carpets laid near a burrow (Bloom 1987). Six gram, necklace style, radio-transmitters, in the 172 MHz range, were used for this study (Holohil Systems Ltd., Woodlawn, Ontario). Subsequent to radio-marking, owls were monitored daily to identify migratory departures. A van equipped with a roof-mounted, rotating, 5-element Yagi antenna was used for local monitoring. Checks early in the morning (<2 hr after sunrise) were the most efficient way to determine a departure from the previous night. Early detection ensures adequate daylight to initiate an aerial search.

Tracking

Three-element, Yagi receiving antennas were securely mounted to the wing struts of a Cessna 185. Using a programmable, scanning, telemetry receiver (Lotek SRX-400, Aurora, Ontario), we scanned for many frequencies while flying. Various systematic search patterns were used, with an interval of about 37 km (20 nmi, nautical miles), or twice the minimum sideways detection distance (Kenward 1987). Limited testing revealed a minimum sideways detection distance of ≈16-21 km from 5000 ft above ground level (AGL). In retrospect, further testing might have revealed greater detection distances from higher altitudes.

When an owl's signal was detected, the aircrew would descend to ≈1000 ft AGL, home in on the signal by circling and record the approximate coordinates of the location. Homing in is more efficient if the pilot can also plug into the receiver and listen to the signal. Upon landing, the coordinates were relayed to the ground crew. The ground crew visually confirmed owl locations, recorded qualitative habitat information and monitored owls to detect subsequent departures. The roof-mounted antenna in the van permitted the ground crew to relocate owls efficiently and monitor their signals from inside the vehicle.

RESULTS AND DISCUSSION

From 10-26 September 1997, 13 burrowing owls from the Moose Jaw, Saskatchewan area were captured and equipped with transmitters. One adult male removed his transmitter within four days. No other owls removed their transmitters or did excessive damage to the antenna prior to leaving Moose Jaw. Only one owl, from the Mealing farm near Moose Jaw, made any pre-migratory dispersal movements. On 22 September, this juvenile (frequency .577) moved 2.8 km at 293°, and stayed there until migrating. The 12 radio-marked burrowing owls departed the study area between 24 September and 17 October (Table 1).

A variety of aerial search strategies were employed during this project, all based on conjecture. These searches totaled 52 flying hours. Owls were often detected from >18 km (10 nmi) away. This suggests that few birds were missed with our 37 km (20 nmi) interval search pattern. More likely, we were just searching in the wrong areas at the wrong times.

Searches revealed five burrowing owl locations south of Moose Jaw, Saskatchewan (Figure 1, Table 2). Three owls were located in southern Saskatchewan on 4 October, the day after their departure from Moose Jaw. Thus, these three locations represent one night of travel for the owls. One owl (.882), moved on the following night. The other two departed the night of 5 October. On 6 October, two owls were detected near Dickinson, North Dakota. One of these (.577) may have been a relocation of one of the owls from southern Saskatchewan on 4 October. However, another owl also carried a transmitter with this frequency. The other owl near Dickinson (.579), had departed Moose Jaw 12 days earlier. Both of these owls resumed their migration on the night of 7 October but could not be relocated. We were monitoring one of them (.577) when it departed at 1940 hrs.

In general, owls departed Moose Jaw in a south-southeasterly direction, migrated at night, and did not necessarily fly every night. Nightly movements (N = 4) averaged 186 km (109-326 km). Casual observations of wind, weather, and moon, resulted in the following, very general, conclusions about burrowing owl migratory movements. They do not seem to fly if they have to fight a strong south wind and appear to be influenced by the prevailing NW winds, i.e, SSE route. In a few cases, owls departed the night before a high pressure (storm

Table 1. Radio-marking and migration information for 13 burrowing owls from the Moose Jaw, Saskatchewan area. Migration departure dates of 12 owls are summarized (mean ± SD).

Frequency (MHz)	Age/Sex*	Marking Date	Marking Location	Migration Departure
172.84	ad/m	10 Sept	golf course	13 Oct
172.882	ad/m	10 Sept	golf course	3 Oct
172.572	ad/m	11 Sept	golf course	3 Oct
172.572	ad/f	11 Sept	golf course	13 Oct
172.605	ad/f	18 Sept	golf course	17 Oct
172.579	ad/m	18 Sept	golf course	transmitter chewed off 22 Sept
172.568	juv	26 Sept	golf course	27 Sept
172.57	juv	12 Sept	exhibition	28 Sept
172.57	juv	12 Sept	exhibition	28 Sept
172.579	juv	12 Sept	exhibition	24 Sept
172.577	juv	15 Sept	exhibition	3 Oct
172.577	juv	18 Sept	Mealing E	4 Oct
172.569	juv	19 Sept	Mealing E	13 Oct
			Mean ± SD	4 Oct ± 7d

* ad, adult
juv, juvenile
m, male
f, female

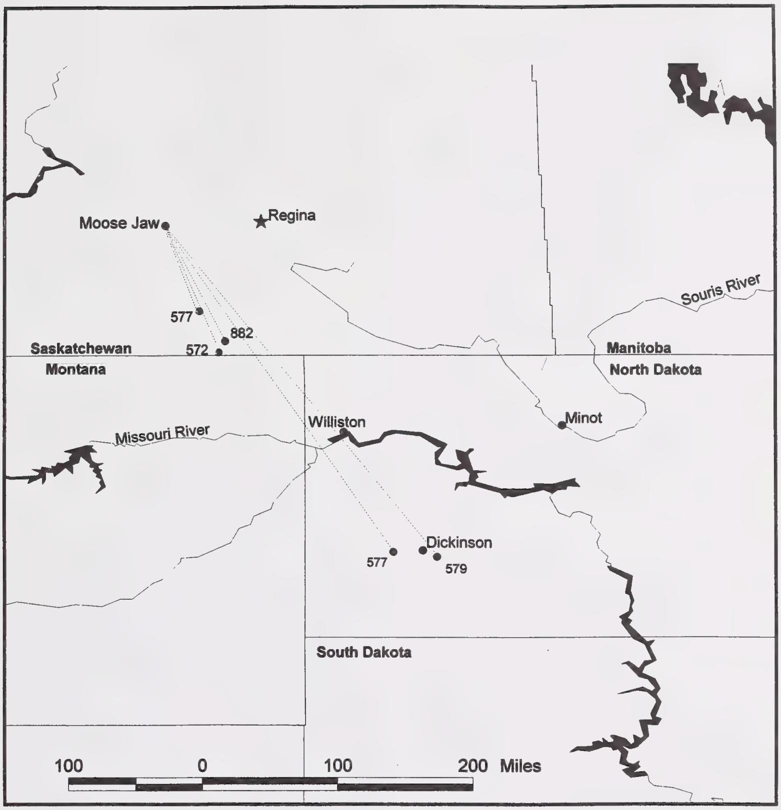

Figure 1. Five roost locations of burrowing owls migrating from Moose Jaw, Saskatchewan.

front) moved in, but never during a storm. They did not seem reliant on moon light for flying. Most of these movements occured when the moon was new to first quarter. Temperature did not appear to be a factor which prompted initial or subsequent migratory movements.

Burrowing owls do not appear to climb to high altitudes to take advantage of the winds while migrating, as many songbirds do. The only evidence of low flying owls comes from two documented departures of radio-tagged owls; Alberta 1995, and Dickinson, North Dakota 1997. Both of these owls were being monitored when they departed. If these owls had gained considerable altitude as they were departing, their radio signals would have increased in strength, and they probably could have been tracked from the ground. Rather, the signals faded quickly as they departed, and could not be relocated from a vehicle.

Qualitative habitat information was collected for the five locations occupied by migrant burrowing owls. The location of .882, near Big Muddy Lake, Saskatchewan, was not confirmed by the ground crew. From the plane, this appeared to be a large tract of native rangeland (≈39 km≈, 15 sections), with no grid roads and only a few winding trails. Near Bengough, Saskatchewan, .577 was found using a burrow in a small tract of heavily grazed native pasture near a dugout. This grassland was surrounded by a stubble field. Further south, .572 was found using an old badger burrow on the slope of a small, ephemeral creek in a moderately grazed native pasture. West of Dickinson, North Dakota, .577 was using a relatively fresh badger burrow in a quarter section of heavily grazed native pasture. East of Dickinson, .579 was using an old badger hole in recovered crop land (CRP), adjacent to stubble. Vegetation on this CRP land was mostly grasses and weedy forbs, up to 30 cm high but fairly sparse. As expected, burrowing owls were using burrows in grazed pastures or areas with

Table 2. Habitat description, distance, and direction of five migratory burrowing owl roost locations from Moose Jaw, Saskatchewan.

Frequency (MHz)	Date Located	General Location	Distance (km)	Direction from N	Habitat Description
0.577	4 October	Bengough, SK	109	167	grazed native pasture
0.882	4 October	Big Muddy Lake, SK	147	162	native rangeland
0.572	4 October	Big Muddy Lake, SK	159	165	grazed native pasture
0.577	6 October	Dickinson, ND	432	155	grazed native pasture
0.579	6 October	Dickinson, ND	452	151	recovered cropland

sparse vegetation. Despite the abundance of prairie dog colonies in North Dakota, no owl was found roosting in one.

CONCLUSIONS

This research was largely exploratory and well within what is referred to as the unknown-unknown realm of scientific investigation (Bauer 1992). That is, we did not have the background knowledge to test hypotheses about migratory strategies or rigorously compare different tracking techniques. This is in contrast to an investigation of the known-unknown, where well established knowledge and theory are used to guide testing of a specific scientific question (e.g., does body condition influence the speed of migration?). We were simply using available information, and drawing on the intuition and experience of a variety of people, to track owls and develop better techniques.

Despite a limited number of relocations, we greatly expanded our knowledge of burrowing owl migration strategies. We have confirmed that burrowing owls migrate at night and use burrows in grazed pastures. We have learned something of the distance and direction of movements. We also examined meterological factors which might influence their departure or route. Perhaps more importantly, though, we have gained insights which will permit greater success in future attempts to track these endangered owls.

PROTOCOL RECOMMENDATIONS

Burrowing owls from within Moose Jaw (golf course and exhibition grounds) should be used again as tracking subjects. Both adult and juvenile burrowing owls typically disperse from their nesting area in late summer (Clayton 1997). These movements complicate local monitoring and determination of migratory departures. This year, Moose Jaw owls did not disperse more than 1 km prior to migrating, whereas many other owls on the study area did.

Ten to 15 transmitters should again provide adequate opportunities for tracking. The Holohil transmitters worked well. A slightly stronger model, weighing ≤7.5 grams, should provide increased range without compromising the owl. Transmitter frequencies should be spaced by ≈20 KHz to allow definitive identification of individuals. Adult owls are more likely to damage transmitters (pers. obs.). However, adults should survive better and possibly migrate more directly than juveniles. Juvenile owls are easier to capture in early autumn. Given these trade-offs, a combination of adult and juvenile owls will suffice for tracking. To facilitate trapping and minimize owl damage to transmitters, radios should be put on in late August. Further testing should be done to determine the optimum altitude for detecting transmitters from the plane. Higher altitude equates with greater range up to a certain point (Gilmer et al. 1981).

Flying at night to track a migrating owl may be more efficient than searching vast areas the following day. However, this strategy introduces a new suite of obstacles, the most significant being the need for a twin-engine aircraft and an IFR (instrument flight rules) qualified pilot. If Yagi antennas are to be mounted on the wing struts, as they were this year, we would require a twin-engine, high-winged aircraft such as a Cessna 337. However, if we can achieve adequate range (>20 km) with omnidirectional antennas (of a length equivalent to 1/4 or 5/8 wavelength), these can be bolted directly to the ventral surface of an airplane wing. This would reduce costs by permitting the use of a Piper Aerostar (low-winged) which is owned by Saskatchewan Environment and Resource Management.

With either of these twin-engine planes and an IFR qualified pilot, flying altitude would not be restricted by the cloud ceiling as it was this year.

For nocturnal tracking to be effective, timely communication between the air and ground crews is essential. Cellular phones, although expensive, are the best means of ground-to-ground communication. Once the plane is up, air-to-ground transceivers should be effective if the ground crew can stay within range (≈50 km).

A brief scenario is the best way to illustrate the nocturnal tracking procedure as we envision it. We have located a burrowing owl by diurnal searching the day after its departure from Moose Jaw. The ground crew would then monitor the owl in the evening to identify its subsequent departure. The air crew would be on standby at the nearest airport. Once the owl departs, the plane could take off immediately and begin searching south of the last known location. Once the signal is detected, the plane would stay in contact with the signal (e.g., by circling) until fuel was required, or the owl stopped and the ground crew could catch up. By directly tracking owls in this way we can learn more about their movement patterns and hopefully follow them more successfully.

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The field crew deserves recognition for their dedicated work on this project. Patrick Derocher (FSIN) was an exemplary student, and quickly developed a knack for trapping and tracking burrowing owls. Ray Longmuir (SERM) and Pat spent many days, and nights, chasing across the mid-west trying to keep up with the air crew. Subsequently, they spent many hours waiting for our phone calls to report owl locations. Bill Wood, our ever dedicated pilot from Athabasca Airways, provided assistance in the field as well as in the air. He even offered the odd lesson on history, hockey, or billiards. Danielle Todd assisted greatly by monitoring the owls remaining in Moose Jaw while we were chasing others in the United States. We personally thank Earl Wiltse for helping to initiate, develop, and support this project.

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READJUSTING ENVIRONMENTAL ETHICS: THE NATURE WITHIN US

Henry T. Epp

Digital Environmental Management Inc., 14 Shawbrooke Court SW, Calgary Alberta T2Y 3G2

Abstract: As the century and the millennium near their joint end, ethics are becoming increasingly important to environmental management. The developing ecocentric ethic, environment first with recognition that humans are part of it, is being promoted by environmentalists as the ethical basis for driving improved actions toward the environment/nature in contemporary technological societies. Research, however, has shown that an ethic is by no means the only driving force behind an action. Environmentalists and environmental managers tend to divide human ethics into pre-technological (people are part of nature) ethics, and technological (the earth is here for human use and abuse) ethics. This paper proposes closing the gap between these ethical polarities while recognising the fact that ethics are not the only driving force behind actions. How to close the gap? First we need to become aware of the reality that a "balanced" nature, the ideal of many environmentalists, is mythical, not real. Nature is non-linear, not readily predictable, and subject to continuous disturbance, and humans are part, but only part, of this. Ethically, we must learn to love nature as we love ourselves, and also to love nature *as* ourselves, the nature within us. Then, we must learn to manage not nature alone, not ourselves alone, but *to manage ourselves and nature together as one interacting s*ystem. The action needs to be driven by our love of nature and ourselves, an ethic, yes, but also by our rational side that relies on knowledge derived from both science and traditional sources.

By deliberately surrounding myself with flowers, I am honouring the part of myself that recognizes the truly beautiful to be more valuable than the merely useful. Freeman Patterson (1997).

INTRODUCTION: SOMETHING IS MISSING

Again and again, while discussing environmental concerns in the 1990s the question of ethics arises. It cannot be avoided. It is central to human belief and behaviour systems, how people relate to other life forms and ecosystems in addition to each other.

Briefly, the evolution of environmental ethics can be traced from the original belief that humans are part of nature (the biocentric ethic), to the idea of manifest human superiority and dominance over nature with the moral right to exploit it (the anthropocentric ethic), to a return to thinking of ourselves as part of, not above, nature, with the added caveat that nature is more important than humanity (the developing ecocentric ethic) (Rowe 1992, Ferkiss 1993, Worster 1994). Added to this now is the presently developing idea of *biophilia,* love of other life forms (cf. Wilson 1996), as a common human characteristic and considered to be an important driving force toward accepting the ecocentric ethic . This historic process, of course, is relevant only to our contemporary technological societies but then these are the ones that are contributing the lion's share to our current environmental problems.

In a previous paper Epp (1997) discussed the potential of the ecocentric ethic to become central to technological civilisation and then driving improved behaviour toward the environment. He tested this hypothesis and found that the ethic does not necessarily drive the action, that more than a revitalisation of an old ethic is needed to stem the current excesses against the environment.

Certainly, in their zeal to moralise environmental management, to take it beyond science and the merely rational, environmentalists have not been above pontificating about ethics. As Epp (1997) has explained, a change in ethics to belief in oneness with nature is no guarantee of a change in behaviour sufficient to solve the problems. But something more also is missing from the environmentalist paradigm. While proclaiming human dependence on and subservience to nature, some environmentalists are falling into the same conceptual trap they denounce in others. They continue to separate humans from nature by defining a pure state of nature as excluding humans. It would seem they have adapted the

Judaeo-Christian belief in the "fall" of humankind to a new end so that the "original sin" is the invention and application of contemporary technology.

Certainly, ecocentric ethicists understand that for half a million or more years human beings have lived as functioning parts of ecosystems, but that was before the technological "fall". Since then, they tell us, people in western technological societies have lived apart from nature, bent on twisting it to suit their own narrow ends to its overall detriment and ultimately their own peril. The only way out of this untenable situation, according to this mantra, is for we technological humans to adopt the ecocentric ethic. Once accepted, the new ethic then will force a condign driving of the required conservation and population control measures.

But is this true? Is our need to believe ourselves to be separate from and above nature so strong that even those denying this belief fall into its own trap, "hoisted on their own petard"?

This paper explores the idea that if humans indeed are part of nature, then what we do is not unnatural. Once we accept this viewpoint, we can begin exploring the hypothesis that there may be other species out there that have exceeded the ability of nature to regulate their populations. Their survival strategies might provide insights on how we may adjust our own behaviour to ensure not only our survival as a species, but survival in tandem with other species and ecosystems. Moreover, if what we do within our environments is because of our human nature, then we can begin to find ways to change our behaviour within these overall confines of our nature. We may seek ways of relating to the environment that include ethical change, indeed, but we need to reach beyond that to change our *behaviour* as promoted in the quote at the start of this paper.

HUMANS AS CONTRIBUTORS TO ECOSYSTEMS

Traditional foraging peoples not only believe themselves to be part of nature, subject to its laws, but contributors to its functions, its ecosystems, in scientific parlance. This viewpoint stands in stark contrast to some post-modern environmentalists taking one cue from the science of ecology, and then promoting the ecocentric ethic and lifeway for technological societies. The notion that humans are contributors to ecosystems as well as affecting them negatively has not yet penetrated deeply into environmental management approaches. The well known tropical forest anthropologist and primate ecologist, Leslie Sponsel (1997), nicely encapsulates this impediment to a more balanced concept of human relationships to the rest of nature:

> Paradoxically, biologists tend to consider [humans] as part of nature in an evolutionary sense, yet apart from nature in an ecological sense. Biological ecologists usually ignore humans as if they were unnatural... Apparently the presence of humans in an ecosystem somehow contaminates pristine nature. Although coevolution is a popular concept in contemporary biology, it has yet to be applied to human predator-prey dynamics, even though such a relationship may have persisted for thousands or millions of years in many regions...The human niche as a feeding strategy can be defined only in relation to other species in the faunal community...

Sponsel clearly identifies the specific problem: inability of humans trained in biological ecology to view themselves as components of ecosystems, as contributing to individual ecosystems in addition to taking from them and affecting them negatively. Environmentalists, many of whom have substantial ecological knowledge and training, recognise technological humans as living within ecosystems, but they too fall short of considering them as components.

Recognising this reality has the potential of providing an important link between the ethic and the needed action.

Taking this step should move the ecocentric ethic from a perception by the public and developers as environmentalist arrogance to comprehension and acceptance by the very people environmentalists are trying to influence, decision-makers. Certainly, indigenous Amazonians recognise the need for adoption of this view of life by outsiders to help them protect the rain forest as home for both humans and other species when they say that the forest's "human inhabitants...are also part of the biosphere..." (Redford and Stearman 1993).

The evolution of human contribution to ecosystems does not need elaboration here. The story is well known, having been told and retold many times as parts of numerous different agendas. In sum, humans originally behaved as both foragers and predators, followed by intensive manipulation of local ecosystems via agriculture and pastoralism, followed by urbanisation and development of the market economy, culminating in the contemporary urban technological civilisation with its global environmental effects.

Human contributions to ecosystems, then, have ranged from being reciprocal, to locally manipulative with consequent minor effects, to global alteration with as yet unknown ecosystem process consequences. Now we have reached the point where we are consistently taking more from individual ecosystems than we are putting back, not only locally but the world over. We also are rearranging the materials and energy flows so that what *is* put back is far removed from its place of origin, with many ecosystems receiving more of our waste materials than they can assimilate into their processes, while others lose nutrients. And we have swarmed in our favoured places, overrunning them with our vast numbers.

BUT WE ARE NOT ALONE

Accepting the idea that humans, even technological humans, belong to ecosystems rather than the other way around, how unique is our experience, the contemporary environmental dilemma we have created? Are there other examples in environmental history of ecosystems being thrown into disequilibrium, out of balance, by huge population increases and/or waste accumulations? If such swarming events by other species have occurred in the past, have ecosystems adapted to such events? If so, how? Are we special now because the readjustment we are causing is global in scope? Equally importantly, if population imbalances occur in nature, can we learn from other species that have had population imbalances within their respective ecosystems? Finding answers to these six questions should help provide a perspective for us technological humans as one agent of environmental change.

Common knowledge is the occasional swarming and population surging of large tropical and subtropical grasshoppers, locusts. These insects tend to migrate or move from place to place when they swarm, eating all soft parts of vegetation in their paths, denuding landscapes. Swarming and rapidly moving locusts are feared greatly by the agricultural and pastoral human groups that happen to lie in their migration paths. Also common knowledge, decades old, is the fact that swarming and migrating locusts suffer severe population crashes after they destroy their own food supply and poison their surroundings with their own wastes (cf. Popov 1958).

Great increases in population are not phenomena restricted to insects. Familiar examples exist among mammals as well. Well known is the population cycle of the North American snowshoe or varying hare (Banfield 1974). Every nine years or so the population builds up to a peak so that the countryside is teeming with hares. Then the population crashes, and begins to build up again, slowly at first and then more rapidly until another peak and another crash occur. Arctic lemmings go through similar cycles, and mouse populations have peaks and crashes as well, although less regularly.

Among larger mammals, the North American plains bison existed in enormous numbers on the Great Plains before being extirpated over most of its range late in the nineteenth century. The great herds moved from place to place, often destroying most of the vegetation in their paths (Roe 1951). Barren-ground caribou in the North American Arctic and African savanna ungulates, such as the wildebeest, behaved and continue to behave similarly, traveling and even migrating in great herds to this day.

All of these extremely abundant mammalian species have two characteristics in common: (1) they are herbivores, and (2) once they surge in population they are no longer regulated by predators. Are these vast populations of some animal species, then, graphic symptoms of ecosystems out of balance, their processes having gone wrong? Or is the idea of "the balance of nature", nature in equilibrium, erroneous in the first place, a utopian end-state existing only in human imaginations?

Much speculation has occurred about the possible causes of population cycles and the enormous numbers of individuals of some species, and many hypotheses have been proffered. The surest knowledge of why some species can exist in vast numbers, far beyond the ability of their predators to regulate them, lies with ungulate mammals. In this regard, Fryxell, Greever, and Sinclair (1988) have demonstrated that those ungulates that do not defend territories are free to move about in search of forage and, given the proximity of habitats that may be used at different times of year, often will migrate annually between these habitats, increasing their food supply. African wildebeest, North American bison, and barren-ground caribou are the best known examples. However, the most significant benefit of migration to ungulates is not improved food supply, but escape from predation.

Most predators are territorial, each individual or group being tied to a relatively small space within one ecosystem. Hence, most predators cannot migrate with their prey. So, if an important prey species leaves a predator's territory for half of each year or so, the food supply alternates between great abundance and great scarcity. That is not conducive to high predator numbers, and the prey species escape being regulated by predators by this one simple adaptation.

This information answers the first two questions posed in this section. Our experiences as a species out of equilibrium with ecosystems, our swarming numbers, and our penchant for poisoning our surroundings are not unique. *So nature out of predator-prey balance is entirely natural!*

Our human notion of a nature in total balance is just that, a notion, *our* idea. The facts speak otherwise. Yes, balances do exist among some species in some ecosystems, but evolution of survival strategies enables some species to move outside these equilibria on occasion.

Are there examples of entire ecosystems having undergone "natural" (non-human caused) "disequilibrium" by the swarming of some species? Certainly, in the case of cyclical population fluctuations among some territorial herbivores, such as snowshoe hares in North America's boreal forest, their own cycle is duplicated by populations of their predators, primarily lynx, the most important difference being a time lag (Banfield 1974). Also, the cyclical herbivores may outstrip their food supplies during population highs, but the population lows are lengthy enough for the vegetation to recover, so the cycles become part of the "system".

As mentioned before, all is not that simple in the case of migratory ungulates. First, these species either are not territorial at all, or the males defend small, temporary, breeding territories (leks), leaving the rest of the year free to travel. Territorial ungulates, however, are not so free to travel, a fact with important consequences. In non-forested southern Africa, those ungulate grazing species in which the males defend definitive territories for most or all of each year, exist mostly in marginal environments. These include the African wild ass which is restricted to semi-desert riparian habitats in North Africa, and Grevy's zebra which is restricted to riparian environments in a few small, semi-arid locales in eastern Africa (Klingel 1972).

In pre-European contact North America, territorial ungulates were restricted to forests, open woodlands, and mountainous environments. Not so the bison and the pronghorn antelope. The bison bull's social strategy revolved around defending a harem of cows during the breeding season, not a piece of land, and the pronghorn antelope males became territorial only temporarily during the breeding season (McHugh 1958, Kitchen 1974). Yet as little as 15,000 years ago, during the waning years of the last continental glacier, what were likely territorial grazers abounded in central North America, outnumbering the bison (Geist 1985). These animal species included horses related to the extant territorial Grevy's zebra in Africa, and camels related to the present territorial South American species (Klingel 1972, Gauthier-Pilters and Dagg 1981).

As the last great continental ice sheet retreated northward, the vast ecosystem to the south of it differentiated sharply, changing from being a woodland-grassland mosaic to well defined open grasslands in the west and forests in the north and east, with only relatively small areas of open woodland remaining in the ecotones and riparian zones (Owen-Smith 1987). It was then that the bison, pre-adapted via their non-territorial social strategy, began to migrate between the woodlands and open grasslands twice annually, large portions of the herds spending the summers on the grasslands and the winters in the wooded areas (Epp 1990). Once this migration pattern was adopted, the herds escaped being regulated by predators and could expand in numbers until regulated only by food supply, disease, and accidents. In fact, numbers likely increased up to tenfold, the normal ratio between migrant and sedentary portions of an ungulate population (Fryxell, Greever, and Sinclair 1988).

Epp (1990) has suggested that it is entirely possible, even likely, that this relatively sudden swarming of the bison population in central North America may have usurped the food supply in the remaining open woodlands so that their territorial grazing competitors, unable to avail themselves of the advantages of migration, were out-competed to the point of extinction, all the while being subjected to year round predation. In similar East African environments, notably the Serengeti-Mara ecosystem where large herds of grazing ungulates migrate twice annually between woodland and open grassland habitats, the territorial ungulate species are limited to a few bush loving antelopes and the black rhinoceros, which is a browser, and not a competitor. Why are there no asses or Grevy's zebras in these ecosystems to which they are so well suited anatomically and physiologically? The only possible answer is that their behaviour does not permit them to compete successfully for forage with the more mobile grazers, who would be able to overwhelm them with a tenfold increase in numbers at least once a year in any habitat they happened to occupy. Furthermore, these territorial species would bear the brunt of predation during the half of the year when the migrant herds are absent.

Have ecosystem processes adjusted in these situations? Obviously not, if predator-prey equilibrium is seen as the ideal. But, ecological equilibrium is a human concept and nature is not goal oriented, so ecosystems do not continually "strive" to be in a state of equilibrium. Obviously, when some species become extremely numerous permanently, competitors must suffer declines. This is how species and ecosystems evolve and even become extinct, simple Darwinistic theory. Some species and some processes are not pre-adapted to be able to withstand sudden, massive, and permanent change, and they become casualties. Yet biodiversity ensures that some life forms and processes do survive, possibly eventually even establishing a new near equilibrium.

In the case of species that swarm cyclically, the effects on ecosystems seem to be less permanent than in the case of migrant ungulates, although devastation may occur temporarily. Examples are some locusts and the hare-lynx cycle in North America mentioned previously. In the latter case, both herbivores and predators have time to adjust to each other's large population fluctuations, and other species are able to adjust too.

These examples provide answers to the second, third, and fourth questions posed at the start of this section. Ecosystems have adapted to both temporary and permanent population surges by some non-territorial species in the past, but the adaptations have not necessarily led to predator-prey balance or equilibrium, and may even have caused other species to become extirpated in individual ecosystems. These examples do not provide precisely definitive answers, but then, that is the nature of nature. The good side of this is that if nature's processes were more precise, more easily defined, species and ecosystems soon would lose their adaptability and then they, we, would soon be extinct.

So, is the present human population surge cyclical or permanent? It may be too early to tell. We no longer have significant predators, and the past cycles of pestilence and population recovery have been greatly minimised in the last several hundred years, so the prognosis leans to the permanent.

The fifth question asks if humans are special because the present effects are global in scope. The answer to this must be yes. Some sea species inhabit most of the oceans, and some land species inhabit several continents. But none come to mind that are capable of influencing the atmosphere, the seas, all of the continents, and possibly even the climate, at the same time. The jury remains out on the extent of our global influence, but there no longer is any doubt that our human influence is global.

Why has the humans species swarmed? We are not consistently herbivores, and we do not migrate *en masse* between two different environments twice each year. Yet the answer is simple. Via our technology we have enabled ourselves to move freely from one ecological niche to another and, even more importantly, to occupy many niches at once. The potential for swarming by a species that can master this challenge is enormous. Add to this the ability to control predation and disease and to increase food supply artificially, and the potential becomes phenomenal. In other words, the swarming of the human population is entirely natural and predictable given the present circumstances.

What, then, can we learn from other species that have evolved or learned a way to escape being regulated and undergo population surges on occasion? In answer to the sixth question posed at the start of this section, the warning signs are there, but we must identify them, and then we must heed them. First, some animals that undergo great population increases occasionally also suffer huge population crashes. The crashes tend to be caused by (1) eating up their food supply, (2) poisoning their environments with their own wastes, and (3) spreading of diseases enhanced by closely spaced individuals. Increased predation tends not to be a significant cause, although it may exacerbate a downward trend in numbers once it has begun.

Second, animals with high populations that migrate seem not to suffer as regular crashes as do those that do not migrate, such as the territorial hares. Continually on the move, these migrant populations are less susceptible to devastation by disease, and they are able to leave places that either are contaminated or have been denuded of food supply.

Clearly, what we can learn and apply to our own situations from this information is that a mobile population is less at risk of a crash than is one that is highly sedentary. People must be free to travel where the resources and jobs are, to move food around to where the people are, and to go where the contamination is not. Annual migration is not a good survival strategy in our present technological economies, but a high level of mobility is a very good prognosis for avoiding problems.

Obviously a mobile strategy is useful only in helping to prevent severe human population crashes given a limitation to surging. The ultimate prevention, of course, must be to avoid the population doubling and redoubling in the next hundred years or so, because the earth can provide only for so many people and then no more, no matter what their survival strategy.

ETHICS AND ACTIONS

The ethical implications of accepting the nature within us are clear. We humans, especially those of us who participate in technological societies, must first accept that we are part of nature, subject to its laws and forces, yet with positive personal feelings toward it as promoted by the ecocentric/biophilia ethic. But something is missing. We need more. We need to do more.

We need to proceed to the next step in ethical progression and accept ourselves as natural, that the invention of technology has not been our "fall" from which there can be no recovery other than to reject it and return to the state of original "purity". We need to accept the fact that our uniqueness is more in the scale of our effects than in kind. We must accept the fact that many of us are part of a technological civilisation, that we are not going to turn back the clock on it and return to being foragers, and we must accept the fact that the remaining foraging peoples have aspirations just like our own. The nature within us, including our feelings toward nature and our economic aspirations, is the same in people dwelling in our cities as it is in extended families of foragers making their living in the tropical rain forests, as made so very clear by Redford and Stearman (1993) in Amazonia and by world-wide polls on environmental opinions conducted by the Gallups (Dunlap, Gallup, and Gallup 1993).

Understanding our nature as humans, that we all have social, economic, and plain survival needs and aspirations, that we all are capable of loving and caring for nature, not just for itself apart from us, but because it *is* part of us, is the ethical paradigm shift we must undergo. Perhaps then the needed action will come easier, driven by understanding and love rather than by loathing of self, as *part* of what we need to protect, so that the ethic and the action become one, not one driving the other.

LOVING NATURE AS OURSELVES

The discussion on environmental ethics by Epp (1997) made it clear that the ethic alone does not drive the action, so more than a change in the environmental ethic is needed to cause the required change in action. What, then, does drive human actions toward nature?

There may be an unconscious aspect to human behaviour. This idea has received a great deal of discussion by psychologists and other behaviour scientists as well as by charlatans and the general public during the last century or so, often creating fierce nature-nurture debates. These debates are not relevant here as this paper is concerned only with conscious human behaviour toward nature, the environment.

What makes us conscious human beings? There is no definitive scientific conclusion available based on reductionist research, yet we must come to grips with our conscious behaviour toward nature long before we ever will know all of the details, else we may never know them for we may be extinct. It seems to me that conscious human behaviour toward nature consists of a mixture of rationality, emotion, spirituality, and faith. How can we bring these aspects of our consciousness together to change our behaviour toward nature?

First it is necessary to address the common assumption that rationality somehow is fundamentally different from the other aspects of our consciousness. This polarity itself is an assumption, a belief taken on faith, and it is this polarity that has done more to alienate science and spirituality from each other than have scientific discoveries. As Sagan (1997) indicates, spirituality in the form of religion based on faith has done a fairly good job of coping with scientific discoveries, including the more disquieting ones such as the extent of the universe and biological evolution. But neither religion nor science as yet has been able to cope with the rationality-spirituality disparity. Perhaps the shock waves that science has sent through the religious communities over the last several hundred years have been because the religious leaders had settled on the wrong articles of faith. These have included belief that the earth was created solely for humans (a faith easily shattered when evidence of the true antiquity of life on earth is produced), belief in the centrality of the earth in the universe, and belief in the immutability of species even while agricultural humans were changing species before their very eyes with selective breeding. What have these beliefs to do with spirituality, the true originator of religion?

The simple truth is that science actually is full of emotion and faith, although spirituality usually is missing. Many scientists believe fervently in their favourite hypotheses, frequently with very little proof, and often argue with each other with intense emotion. Sometimes some even physically attack others, as happened to Edward O. Wilson during his sociobiology presentation at the 1977 annual conference of the august American Association for the Advancement of Science (Wilson 1994).

So far, there has been very little room for spirituality in science, perhaps because the spiritual side of human nature cannot easily be subjected to analysis. Yet the reverse is true quite often as religion incorporates the findings of science into its tenets, as mentioned previously. This does not mean, however, that spirituality has no place in environmental management. Already decisions are being made in many places that incorporate the spiritual feelings of traditional and other peoples, especially as these relate to sacred sites. Moreover, some environmentalists are promoting spiritual feelings as important in establishing an ecocentric ethic among technological populations.

This paper is not nor can it be a guide on how to incorporate spiritual and emotional feelings into environmental decision-making. The emphasis here is less on how to change our ethics than on how to change our actions, our behaviours, which are partly, but only partly, driven by our ethics. They also are driven by our rationality and by our faith in our ability to accomplish the needed changes. The mix is complex and changeable.

What will drive the needed actions? To me, it would seem to be the ethic plus our rationality regarding economic aspirations, combined with our emotions, forged into a faith that it needs doing, that we can get the job done, and that we *will* do it, that will drive the action.

Changing our anthropocentric ethic to a more ecocentric one is important, but we also must work toward redirecting our emotions. We know already that the ethic is undergoing some change, and we understand the need for practicality and rationality in our behaviours to the environment. Now it is time also to focus on the not so rational, to develop a faith in our own selves as being natural. And it is faith in our ability to accomplish this goal that will, in turn, guide our feelings or emotions relating to the nature within us.

The Judaeo-Christian heritage of many people in western technological societies teaches us to love our neighbours as ourselves. Lasting for millennia, this social behaviour goal for recalcitrant humans is as fresh today as when it was first uttered. But now the time is here to extend the better part of our tradition and behaviour to that of which we are part, which contributes to our existence and to which we contribute in so many ways, the environment, nature, and to reach beyond the ecocentric/biophilia ethic to an even greater inclusiveness. Our universal human challenge now is not to manage nature alone, nor to manage ourselves alone, but *to manage ourselves and nature together as one interacting system,* and to do this from a basis that includes the human emotional and spiritual aspects as well as science. It is time to begin to *love nature as ourselves.*

The meaning of this modified old phrase is simple: to change our behaviour toward nature we must not only revere it as the ecocentric ethic proclaims, but we must also develop an emotion for nature that we already feel for our human families, ourselves. We must learn to love it and not just the other life forms within it. The meaning here is double - we must love nature as we love ourselves but also *as* ourselves. This because we are part of it. We are nature, just as it is us.

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THE PRAIRIE BIODIVERSITY STUDY: COMMUNITY VEGETATION SURVEY

Ann K. Gerry, Robert A. Wright and Joyce Belcher

Saskatchewan Environment and Resource Management, 3211 Albert Street, Regina, Saskatchewan S4S 5W6

Abstract: The Prairie Biodiversity Survey (PBS) is part of the larger Prairie Biodiversity Study. The PBS was undertaken in order to gain much needed community diversity information on the remaining mixed-grass prairie in Saskatchewan. A second objective of the project was to test whether grassland community diversity could be predicted using enduring landscape features. Although enduring features are being used as a basis to select areas representative of the range of biodiversity at national and provincial levels, the nature of the relationship between enduring features and biodiversity has not been explicitly tested.

Data were collected from areas in southern Saskatchewan that differed in three enduring features: landform, parent soil material, and soil texture. Study areas were subdivided by the different soil associations present and random sites were surveyed in each subdivision. For every site all species present in a 64 m^2 quadrat were recorded and their covers estimated. Data were analyzed using multivariate statistics. Examination of the data revealed no consistent relationship between enduring landscape features and community diversity. The number and identity of community types differed between areas having the same enduring feature combination and were similar between two areas having different enduring feature combinations. An examination of actual soil textures and aspects measured at each site indicated that these factors, while not predictive, may be more important than large scale, mapped enduring features in influencing community composition and distribution. The results of this study indicate that a finer scale approach than enduring features analysis is needed to identify, and thus project, the full range of biodiversity.

USE OF MANAGED AND NATURAL WETLANDS BY UPLAND BREEDING SHOREBIRDS IN SOUTHERN ALBERTA

Cheri Gratto-Trevor

Canadian Wildlife Service, Environment Canada, 115 Perimeter Road, Saskatoon, Saskatchewan S7N 0X4

Abstract: Wetlands managed primarily for the benefit of waterfowl production are becoming more and more common in many areas of the Canadian prairies, but we do not known how these changes in water regime and grassland cover will affect other species, such as shorebirds. Therefore, densities of upland breeding shorebirds, especially marbled godwits *(Limosa fedoa),* willets (*Catoptrophorus semipalmatus*), and long-billed curlews *(Numenius americanus)* were compared among areas with managed, natural, and no wetland basins in southern Alberta. Shorebird surveys were carried out by all terrain vehicle (ATV) from 1995 to 1997. Willets, and to a lesser extent marbled godwits, were seldom found in areas without shallow wetlands. Conversely, long-billed curlews were least common in areas near managed wetlands. Four transects changed from 'dry' in previous years to 'wet' in 1997. In these four sites, numbers of willets, but not godwits, increased significantly in 1997. Using information from areas with known numbers of marked willets and godwits, I found that only about a tenth of birds with active nests, in comparison to more than half of birds with broods, were seen during the surveys.

INTRODUCTION

Massive changes in the prairie landscape have occurred and are expected to continue, due to agriculture (including grazing), development, irrigation, and drought. Shorebirds are an important component of prairie ecosystems, but prairie breeding shorebirds have been virtually ignored in research and management studies. This is of particular concern since grassland cultivation in prairie Canada and the United States has resulted in significant range reductions of most prairie-nesting shorebirds (Howe 1982), and, other than in the arctic, the greatest number of North American species of shorebirds breed on the prairies (Godfrey 1986). Trend analysis of Breeding Bird Surveys indicate significant declines in numbers of marbled godwits (*Limosa fedoa*), willets (*Catoptrophorus semipalmatus*), and Wilson's Phalaropes (*Phalaropus tricolor*) in the prairies from 1980 to 1992 (Hines et al. 1993). Recently, marbled godwit and long-billed curlew (*Numenius americanus*) were two of the highest shorebird species listed in terms of potential population vulnerability by a group of North American shorebird experts (B. Harrington, pers. comm.). One of the major reasons given for the high listing of marbled godwit was the almost total lack of knowledge about the species. Numbers of long-billed curlews have been declining in parts of their range (Allen 1980, Page and Gill 1994).

In Canada, breeding densities of western willets and marbled godwits are greatest in southeastern Alberta (Nowicki 1973, Hines et al. 1993), where large areas of prairie are grazed by cattle and water control structures are common. If populations of these and other upland prairie breeding shorebirds are to be sustainable, we must understand how these developments affect all aspects of the ecosystem, including nongame species. Intensive management aimed primarily at production of waterfowl is taking place in many areas of the Canadian prairies. Although waterfowl responses to wetland development projects are being evaluated in some areas, it is not known how these changes in water regime and grassland cover will affect other species. To efficiently direct conservation efforts, one must be able to identify the most important habitats for species of concern and determine how most accurately to monitor populations. Therefore, the objectives of this study were to census areas of managed wetlands, natural wetland basins, and no wetland basins to determine habitat preferences and breeding densities of upland breeding shorebirds, especially marbled godwits, willets, and long-billed curlews; and to determine the accuracy of survey techniques by carrying out surveys in areas with marked birds.

STUDY AREA

The general study area was in the vicinity of Brooks in southeastern Alberta. Much of this semi-arid area is used for cattle grazing. Oil development is common and many of the wetlands that still contain water are managed. An intensive study area, where nests were located, was on the Kitsim complex, a Ducks Unlimited (DU) wetland project 10 km SW of Brooks. In the early 1980s DU connected more than 50 wetlands, allowing irrigation water to be fed into the basin from the Kitsim Reservoir. Wetlands are flooded in spring and fall. The land is owned by the Eastern Irrigation District and is used year-long for grazing and oil and gas development.

METHODS

Surveys

Surveys for willet, marbled godwit, and long-billed curlew pairs were adapted from the methods of Ryan et al. (1984) and Ryan and Renken (1987) and carried out by all terrain vehicle (ATV) in areas of managed wetlands, natural wetland basins and no wetland basins. Sixteen transects were surveyed in 1995. An additional five were added in 1996 and continued in 1997, for a total of 21 in those years (Figure 1). Six (1995) to eight

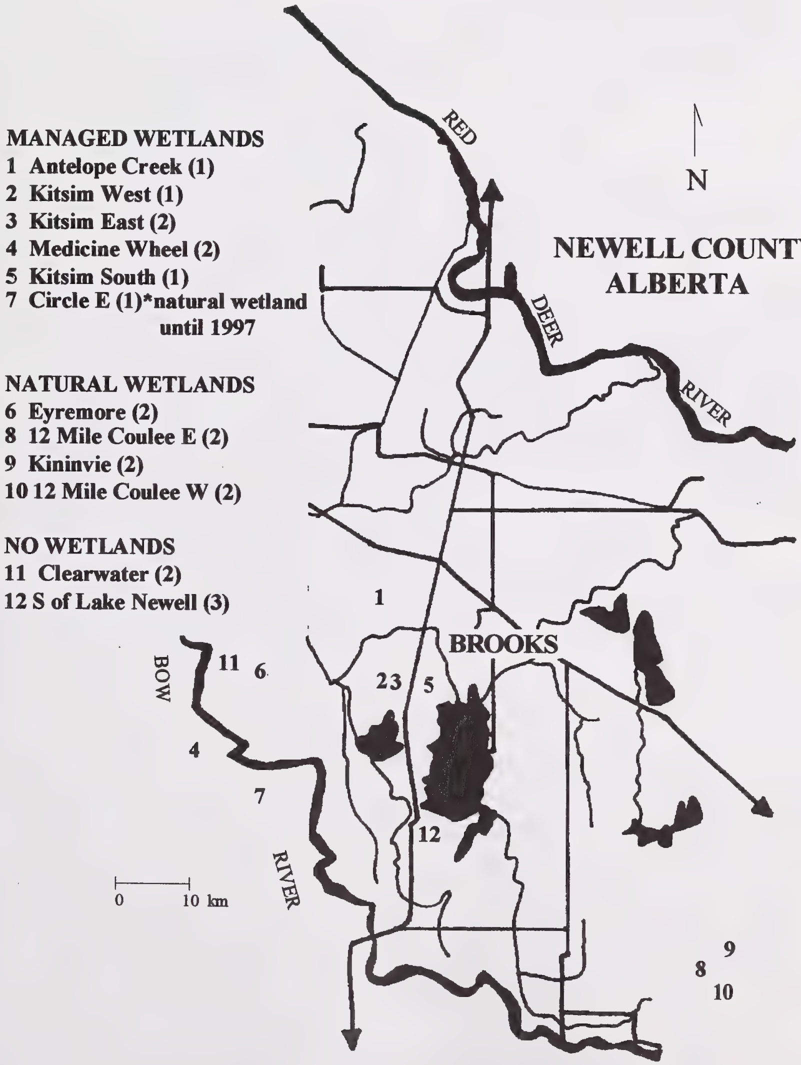


Figure 1. Survey sites near Brooks, Alberta. Numbers in parentheses after survey locations represent number of 5 km transects per site.

(1996-7) were in areas of managed wetlands (one transect was in an area of natural wetland basins before 1997), six (1996), eight (1997) and nine (1996) in areas of natural wetland basins and four (1995) to five (1996-7) in areas with no wetland basins. Each transect was five km in length, measured by ATV odometer. Surveys were carried out three times a year in mid May (prelay/incubation), mid June (incubation/brood care) and early July (brood care). Each transect was slowly travelled by ATV, stopping at least every 300 m. Areas within 250 m of the transect on all sides were then scanned for shorebirds, using 9X36 binoculars. Location and behaviour of all shorebirds were noted as well as extent of wetlands. Birds were only considered to be in the transect if they landed in, flushed from or flew over while vocalizing, within 250 m of the transect line.

Accuracy

On three managed wetland transects, intensive nest searching was carried out, primarily by a waterfowl chain-dragging crew. All nests in the transect area were marked and monitored for success or failure. Adult willets and godwits were captured on nest with mist nets or walk-in nest traps and given individual colourband combinations. None deserted as a result of trapping or marking activities. During surveys at these sites, banded adults were recorded to determine percentage seen of birds known to be (about to be or that had been) nesting, or with broods, on transect.

RESULTS

For all species, results were very similar when either total birds or total estimated pairs was used. Therefore, only pair data are shown.

Managed Versus Natural Versus No Wetland Basins

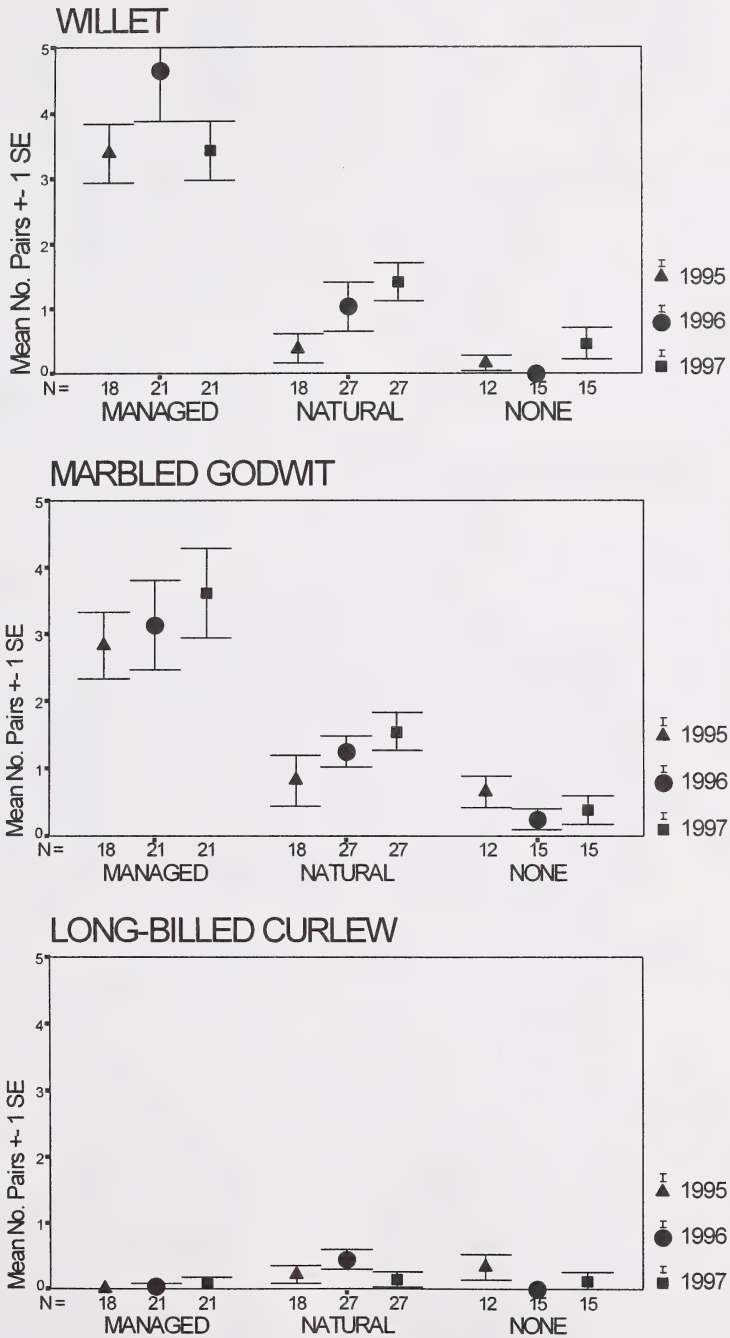
Comparing pairs in managed, natural, and no wetland basin transects, average numbers of Willets and godwits were always highest in areas with managed wetlands, usually intermediate in natural wetland basin sites, and lowest in no wetland basin areas (Figure 2). In contrast, long-billed curlew numbers were almost always lowest in areas with managed wetlands. An ANOVA with wetland type, year and survey period (May, June or July) as main effects was run for each species. For all species, only wetland type was significant (willets and godwits: $P<0.001$; curlews: $P=0.04$). Individual ANOVA tests with Tukey's Family Error Contrasts were run for each species, year and survey to determine which wetland types were most and least used by the birds. With low densities, no comparisons were significant for long-billed curlews ($P>0.05$). For willets, seven of the nine ANOVA tests were significant. In all seven cases, numbers in managed wetlands were significantly higher than numbers in no wetland basin sites. In four instances, numbers in managed wetland areas were also significantly higher than those at sites with natural wetland basins. Six of nine ANOVA tests were significant for godwits. Again managed wetland sites had significantly more birds than no basin areas in these cases, and in four instances managed sites also had significantly more birds than natural wetland basin areas.

Wet Versus Dry Transects

Most of the natural wetland basins were dry during the years of the study. Therefore, to better describe amount of water present, survey sites were split into two categories: those where water made up more than 5% of the transect survey area ('wet'), and those where wetlands were less than 5% of the area ('dry'). Willet and godwit pairs were always more common in wet than dry areas, while the reverse was normally true for long-billed curlews (Figure 3). An ANOVA with 'water' (wet vs. dry), year and survey period (May, June, or July) as main effects was run for each species. For willets, water was highly significant ($P<0.001$) and year barely so ($P=0.04$). There was also a significant interaction between water and year ($P=0.02$). For marbled godwits only water was significant ($P<0.001$) and the same was true for long-billed curlews ($P=0.03$). In every year and survey for willets, and seven of nine comparisons for godwits, wet sites had significantly more birds than dry transects (t-tests, $P<0.05$).

Between-year Changes in Wetland Conditions

As 1997 was the wettest year in the study, some sites changed from 'dry' in previous years to 'wet' (>5% of transect area was wetlands) in 1997, including Eyremore1, Clearwater1 and Twelve Mile Coulee West1. Circle E's newly created wetlands also changed that site from 'dry' to 'wet' in 1997. To examine changes in numbers of willets and godwits at these four sites, compared to sites that had been 'wet' in all years and those that had been 'dry' in all years, an ANOVA with survey and water change (all wet, all dry, change from dry to wet) as main effects was run for each of the three year-pair combinations (1996 vs. 1995, 1997 vs. 1995, 1997 vs. 1996). Survey was never a significant effect, nor was the interaction between survey and 'water change', for either species. As expected, 'water change' was not a significant effect in the 1996 versus 1995 comparison. That is, numbers of godwits or Willets did not change significantly between 1996 and



igure 2. Mean number of willet, marbled godwit, and long-billed curlew pairs observed from 1995 to 1997 at tran-ects in areas of managed wetlands, natural wetland basins, and no wetland basins in southern Alberta. Error bars epresent standard errors. N= number of surveys.

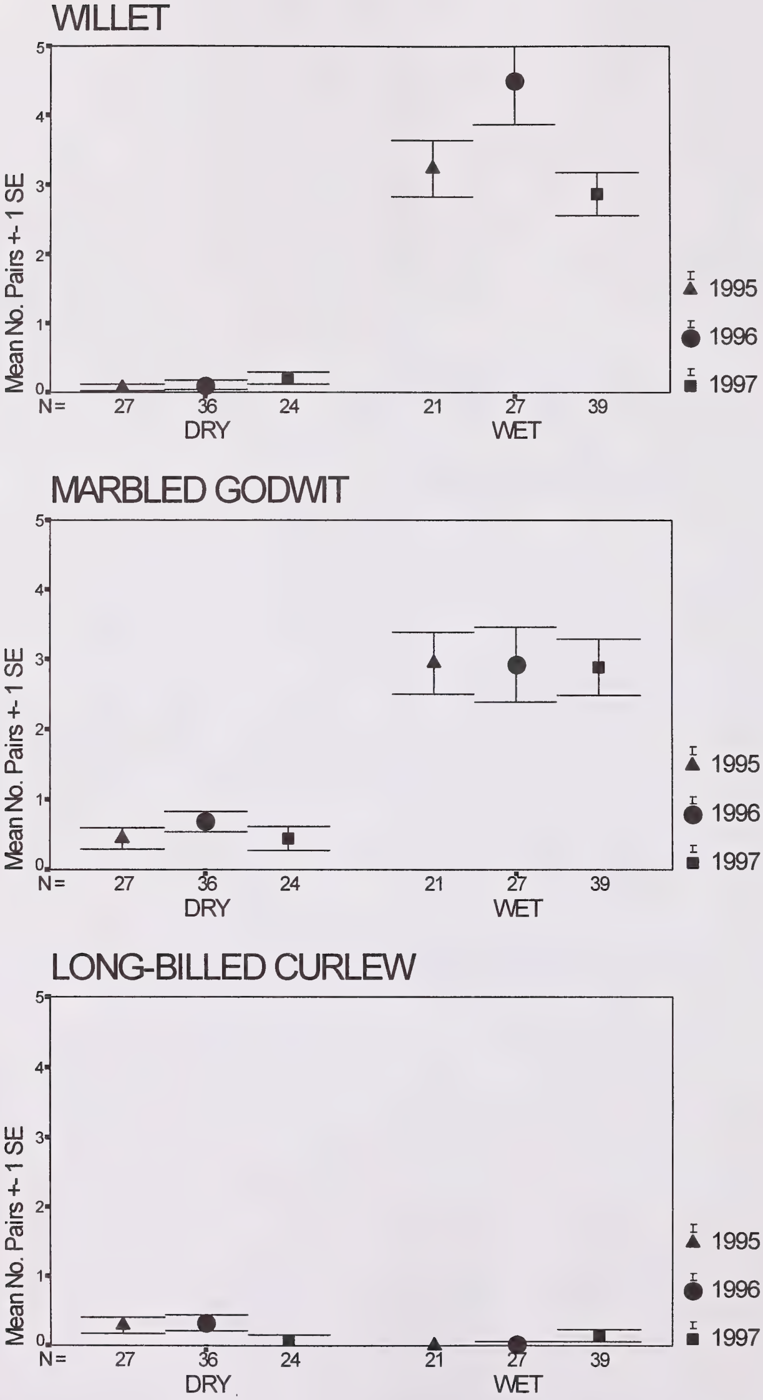


Figure 3. Mean number of willet, marbled godwit, and long-billed curlew pairs observed from 1995 to 1997 in southern Alberta at transects with less than 5% water ('DRY') and more than 5% water ('WET') per total transect area of 5 km X 0.5 km. Error bars represent standard errors. N= number of surveys.

1995 at sites which were wet in all three years, versus sites that were dry in all three years, and those that were dry until 1997. Since the changes occurred in 1997, one would not expect a difference between 1995 and 1996. For godwits, 'water change' also was not a significant effect in the 1997-1995 comparison, but the difference was almost significant in 1997-1996 (P=0.054; Figure 4). However, in both 1997-1995 and 1997-1996, willet numbers increased significantly more at dry sites that became wet in 1997 than at sites that stayed dry, or those that were always wet (1997-1995, P=0.002; 1997-1996, P=0.001; Figure 4).

Accuracy of Surveys

In order to determine the accuracy of the census, during surveys in the intensive study area I noted whether godwits or willets were banded. I calculated the number of banded birds potentially in the transect area at the time of the survey, that is, how many birds had been marked on nest within 250 m of the transect line and how many marked birds were with broods in that area.

Years, surveys and species were combined, because results for willets and godwits were very similar. Overall, 29% (2/7) of prelaying birds (i.e. birds that nested in the transect area within a week after the survey), or 25% (1/4) of prelaying pairs were observed during censuses. Only 7% (6/84) of birds with active nests or 12% (6/51) of incubating pairs were seen, and 20% (16/80) of birds with failed nests that had nested in the transect area. Of marked adults with broods that had been seen in the transect area a few days before or after

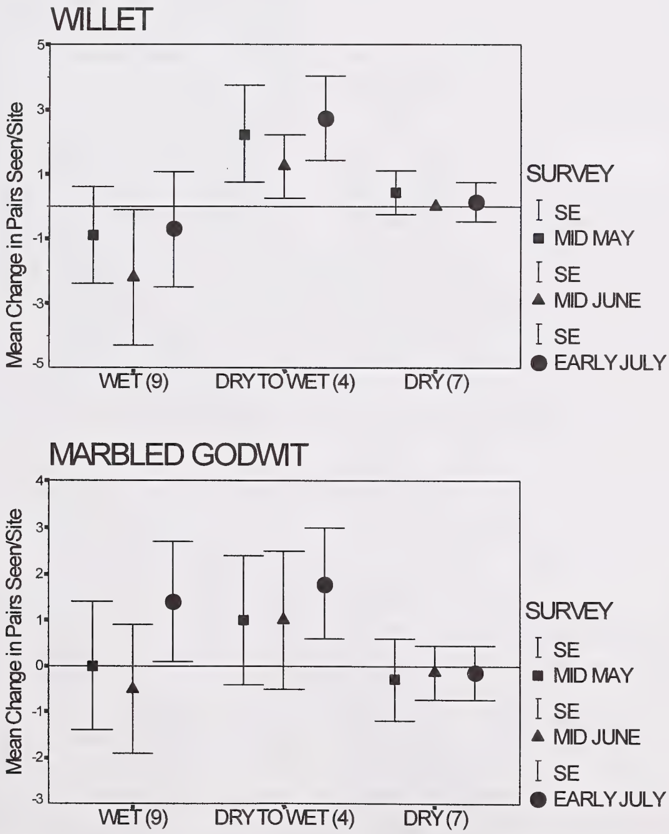


Figure 4. Mean difference in willet and marbled godwit pairs seen per survey between 1996 and 1997 in southern Alberta at sites that had more than 5% water per transect both years ('WET'), less than 5% water both years ('DRY'), and changed from less than 5% water to more than 5% water between years ('DRY TO WET'). Error bars represent standard errors. Numbers in parentheses are number of transects.

a census, 42% (32/76) were seen during a survey, or 48% (28/58) of pairs with young.

DISCUSSION

While observed numbers of willets and godwits were highest at managed versus natural or no wetland basin sites, the difference can be explained by the presence or absence of shallow water. In areas with managed wetlands, water was always present, but most natural wetland basins in southern Alberta were dry during this study. Interestingly, long-billed curlews were generally least common in managed wetland transects or areas with substantial amounts of water. This agrees with studies of long-billed curlew habitat preferences elsewhere, where the birds nested in dry open prairie in Saskatchewan (Maher 1973). In Oregon, curlews nested in highest densities and were most successful in low, open habitats (Pampush and Anthony 1993), while in Idaho they nested most commonly in heavily grazed areas of short grass prairie, and reproduced most successfully in dry years when vegetation was low (Jenni et al. 1982, Redmond 1986, Redmond and Jenni 1986).

From the survey results it appears that godwits, while most common in areas with shallow water, are not as tightly tied to local water conditions as are willets. Willets were rarely observed in 'dry' transects, and then only near the rare wet sites present. Their willingness to move breeding locations according to water conditions was particularly evident in 1997, when wetlands in unmanaged areas especially had more water than in the previous two years. Four survey sites contained significantly more water than in the past (three due to natural changes in water from snowmelt and rain and one from recently created wetlands that were filled in 1997). Numbers of godwits changed little in those sites from year to year, although there appears to have been a slight overall increase. However, numbers of willets increased significantly at those areas in 1997, while numbers did not increase in sites that were always dry or those that were always wet. There was some indication that numbers in 'always wet' sites decreased slightly, presumably because willets spread out into areas not used in previous years due to the increase in numbers of ephemeral wetlands. A similar situation was described in North Dakota, where a decline in breeding willets was observed in drought years when availability of shallow, less permanent wetlands was reduced (Ryan and Renken 1987).

Results from the 'accuracy' tests of the census were not intuitively obvious before the study began. Generally, when one sees a willet or marbled godwit during the breeding season, it is noisily circling one's head. Since both members of the pair share incubation in these species (Vogt 1938, Nowicki 1973), I assumed that the defending adult was either the incubating bird flushing when one was still some distance from the nest, or the non-incubating parent while the incubating bird remained on the eggs. From my work in the intensive (managed wetlands) study area, it is now evident that the incubating bird sits tight, normally flushing only when one is within a very few meters of the nest. The off-duty parent apparently does not stay near the nest, but forages at nearby wetlands, aiding in nest defence only after the incubating bird is flushed. However, behaviour changes dramatically at hatch, with parents vociferously defending their young and often chasing after potential predators still several hundred meters from the brood. Even before the clutch is initiated, willet and godwit pairs in the intensive area seem to spend little time in the vicinity of their nest sites and foraged together at the nearest wetland.

With such a small percentage of pairs seen near their nests during incubation, it is difficult to tell whether the surveys truly reflect differences in nesting densities among managed, natural or no wetland basin sites. Certainly broods of willets and godwits are taken to wetland edges shortly after hatch, but I do not know if birds seen near wetlands during the incubation period are nesting in the vicinity or have travelled some distance to forage there. Future studies will look at nesting densities more accurately via intensive nest searches at natural and no wetland basin areas (which were not nest-searched in this study), as well as at managed sites.

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PERIPHERAL POPULATIONS OF PRAIRIE SMALL MAMMALS: DISTINCT POPULATIONS REQUIRE DISTINCT CONSERVATION APPROACHES

David Gummer

Biology Department, University of Saskatchewan, 112 Science Place, Saskatoon, Saskatchewan S7N 5E2

Abstract: Many rare and endangered species occur in the Canadian prairies at the peripheries of their species distributions. Peripheral populations usually exist in different environmental conditions than core populations and therefore we cannot necessarily generalize species traits between populations to rationalize models and management regimes. I am studying the behavioural and physiological ecology of the northernmost Ord's kangaroo rats and black-tailed prairie dogs to determine if peripheral populations of these two different animals share qualities that are important to consider for conservation purposes. I expect that life history traits (litter size, longevity, sexual maturity) and physiological considerations (body size, body composition, microclimate, thermoregulatory strategies) of northernmost populations vary predictably from those characteristics of more southern conspecifics. These variables are critical parameters in wildlife models; yet, one common approach is to assume that a particular population of a species shares such traits with other populations of the same species. Rather than endeavoring to accumulate population specific data for every species of concern, I suggest that conservation biologists examine the characteristics of a few representative peripheral populations to gain general insight into the ecological consequences of peripheral occurrence. A better understanding of the geographic basis for intraspecific biodiversity should provide a good knowledge base upon which to construct models, conduct sensitivity analyses, and assemble management plans for wildlife at risk.

INTRODUCTION

Many rare and endangered grassland species are widely distributed in the Great Plains of North America between northern Mexico and southern Canada. Most of these species occur in the Canadian prairies only at the northern peripheries of their ranges (Committee On the Status of Endangered Wildlife in Canada 1997). Across their geographic ranges, these widespread species can inhabit vastly different environmental conditions. Early biogeographers first recognized that animals' characteristics (e.g., body size and allometry) vary predictably along climate gradients (Mayr 1963, Allen 1877, Bergmann 1847). One of the most conspicuous climate gradients for many grassland species is that associated with their latitudinal extents.

Geographic variation in organisms' traits is important to consider for conservation programmes. Yet biologists often develop conservation models for one population according to the behaviour and life history characteristics gathered from other populations of the same species. Furthermore, an emerging goal for conservationists is protection of biodiversity. If only the core populations of endangered species are protected then the genetic diversity and long-term persistence of those species may be compromised. Genetic biodiversity, which can be spatially distributed amongst 'island' populations (Hughes et al. 1997, MacArthur and Wilson 1967), may be as important to conserve as interspecific biodiversity (i.e. species richness, Hughes et al. 1997, Myers 1997). Peripheral populations probably play important roles in determining species' persistence in changing environments.

Two prairie rodents that are considered common and widespread in the Great Plains of North America are Ord's kangaroo rats (Heteromyidae: *Dipodomys ordii,* henceforth kangaroo rats) and black-tailed prairie dogs (Sciuridae: *Cynomys ludovicianus,* henceforth prairie dogs). Both of these species are considered 'vulnerable' by the Committee On the Status of Endangered Wildlife in Canada (1997) primarily because of occurrence in Canada at the northern peripheries of their ranges and in restricted areas (Gummer 1995, Lainge 1988, Gummer in prep.). Similarly, the Saskatchewan Conservation Data Centre (1997) ranks both species as 'imperiled due to rarity' provincially (S2) and the Alberta Wildlife Management Division considers kangaroo rats as 'at risk' (blue list; 1996, Gummer 1997a).

Kangaroo rats and prairie dogs are analogous to one another in terms of their geographic ranges, conservation statuses, and justifications for their protection. However, they are very different animals with respect to their natural histories, phylogenies, and life histories.

Kangaroo rats are small (52 g; Jones 1985), nocturnal, myomorph rodents that occupy sandy, arid grassland and shrubland areas (Garrison and Best 1990). They are bipedal and highly fossorial. Their diet consists primarily of seeds, which they collect in their cheek pouches and store in underground food caches. Kangaroo rats are best known for their ability to conserve water in hot, dry environments (French 1993). They are not known to hibernate in natural settings (French 1993). Kangaroo rats have been extensively studied across much of their range (Garrison and Best 1990) but the northernmost population is poorly understood. Elsewhere in their range, kangaroo rats breed at irregular intervals in response to the favourable conditions that result from relatively unpredictable precipitation events (Best and Hoditschek 1986, Kenagy and Bartholomew 1985, Hoditschek and Best 1983, Beatley 1976, Beatley 1969). Individual females reproduce twice per year (Best and Hoditschek 1986, McCulloch and Inglis 1961) and average litter size is 3 (Day et al. 1956). Kangaroo rats are aggressive, territorial animals that maintain a solitary existence (Randall 1989, Eisenberg 1963). As is the case for many desert animals, they are quite long-lived for their body size (maximum 3 years; Brown and Harney 1993, Kenagy and Bartholomew 1985) but they are relatively short-lived compared to larger animals that breed more slowly.

In contrast to kangaroo rats, prairie dogs are relatively large (700 g; Hoogland 1995), diurnal, ground squirrels that live in short-grass prairie areas with deep alluvial and colluvial clay soils (Hoogland 1997, 1995; Canadian Plains Research Center unpubl. data). Prairie dogs are quadripedal and highly fossorial, and they are mainly herbivorous (Hoogland 1997, 1995). They are not known to hibernate in nature (Hoogland 1995). Prairie dogs have been studied intensely in several southern locales but there have been no direct ecological studies of the northernmost prairie dogs. In core parts of their range, prairie dogs reproduce predictably each spring with individual females producing one litter per year with an average litter size of 3 (Hoogland 1995). Prairie dogs are highly social animals and they live in large colonies (Hoogland 1997, 1995; King 1955). They are relatively long-lived: individual prairie dogs can live as many as 8 years (Hoogland 1995).

Clearly then, kangaroo rats and prairie dogs represent different life history 'strategies' (*sensu* Stearns 1993, Pianka 1970, MacArthur and Wilson 1967). Yet, northernmost peripheral occurrence may have caused both animals to adopt similar behavioural, life history, and physiological characteristics that facilitate survival at relatively high latitude.

I am studying the behavioural and physiological ecology of the northernmost kangaroo rats and prairie dogs to determine if peripheral populations of these two different animals share qualities that are important to consider for conservation purposes. I hypothesize that life history traits (litter size, longevity, sexual maturity) and physiological considerations (body size, body composition, diet, microclimate, thermoregulatory strategies) of northernmost populations vary predictably from those characteristics of more southern conspecifics.

I began my research in 1994; however, I will not complete my intraspecific studies and more integrative, comparative analyses until 2002. Hence, I herein present the background information, methodology, and significance of my research activities regarding the conservation biology of peripheral populations. Refer to my MSc. thesis (Gummer 1997b) and forthcoming publications for specific analyses.

METHODS

For both my kangaroo rat and prairie dog studies, my major field activities are: (i) live capture and examination of individual animals (mark/recapture); (ii) seasonal radio telemetry; and (iii) microclimate measurement.

I mark individual animals with uniquely numbered metal eartags (National Band and Tag Co., Newport, Kentucky) and subcutaneous microchips (PIT tags; Avid Canada, Calgary, Alberta). For selected individuals, I attach miniature temperature sensitive radio transmitters as collars (Holohil Systems Inc., Carp, Ontario and AVM Instrument Company Ltd., Livermore, California). I use automatic dataloggers (Campbell Scientific Inc., Edmonton, Alberta and Onset Computer Corp., Pocasset, Massachusetts) to monitor microclimate and I opportunistically obtain regional weather data from Environment Canada (unpubl. data). I georeference all field data using a handheld Global Positioning System (GPS; Magellan Systems Inc., San Dimas, California).

Kangaroo Rats

I study kangaroo rats in and adjacent to the proposed Suffield National Wildlife Area (SNWA; 50° 28'N 110° 32'W), Alberta, where I have worked since 1994. SNWA occupies the easternmost 459 km^2 of Canadian Forces Base (CFB) Suffield. CFB Suffield is used intensively for mechanized army training; however, SNWA has been recognized as an environmentally sensitive area since 1971 and has been set aside as a buffer-zone between civilian land and areas used for live-fire of field artillery, tanks, and small-arms weapons. Eolian sand dunes, stabilized by native grassland and scrub vegetation, characterize 47% (214 km^2) of SNWA (Adams et al. 1997, MacDonald 1996, Usher and Strong 1994, McNeil 1993, Stevens 1972, Reynolds and Armbruster 1971). Presently, 35% (159 km^2) of SNWA is used for rotational cattle grazing by the Prairie Farm Rehabilitation Association (PFRA). There is a dense array of gas pipelines and trails maintained by the Alberta Energy Company (AEC) such that at least 16% (73 km^2) of SNWA has been directly affected by AEC activities. Although accidental grass fires are extinguished by CFB Suffield personnel, 34% (156 km^2) of SNWA reportedly burned between 1983 and 1994.

Kangaroo rats are most active aboveground and susceptible to capture during the darkest phase of the lunar cycle (Kaufman and Kaufman 1982, O'Farrell 1974) and during the snow-free months (Gummer 1997b, Kenny 1989, O'Farrell 1974). Thus, I typically concentrate my live capture activities during the new moon period of each month between April and November.

I survey sparsely-vegetated, sandy habitats for kangaroo rats by a variety of methods. The most productive technique for capturing kangaroo rats routinely and consistently has proven to be nightlighting (Gummer 1997b, Gummer et al. 1997, Ralls and Eberhardt 1997, Steenhof and Sundberg 1992, Barnes and Tapper 1985, Kaufman and Kaufman 1982) which involves driving a vehicle (< 25 km h^{-1}) at night with its headlights on and with 2 spotlights (Brinkmann Corp., Dallas, Texas) aimed at open habitats along the edges of vegetation. When a kangaroo rat is observed, one person attempts to capture it by hand while another person keeps the kangaroo rat illuminated. Habitats that cannot be driven (e.g., actively eroding sand dunes) are searched on foot with bright flashlights (Gummer 1997b). As a subsidiary capture method, I also set Sherman live traps (10 x 10 x 30 cm) to catch kangaroo rats. I bait the traps with whole oats (Gummer 1997b, Kenny 1989) and I place polyester fiber-fill (Doubletex Inc., Winnipeg, Manitoba) in each live trap for bedding material (Gummer 1997b, Radvanyi 1964). I set traps in 15 m grids on sand dunes as well as intensively around active burrow sites and run-ways. Live traps are relatively unproductive because of incidental captures of other rodents, kangaroo rats rendering the traps nonfunctional by kicking sand in/on them (O'Farrell et al. 1994), and the "trap-happy" nature of individuals after their first capture (Kenny 1989). Therefore, I purposely keep the live trap effort minimal in comparison to nightlighting.

Regardless of capture method, I record the following data from each kangaroo rat: body mass, gender, reproductive status, age-class, parasites, and food items contained in cheek pouches. Body mass is determined by placing the kangaroo rat in a cotton bag and measuring its mass using a spring-scale.

Prairie Dogs

I study prairie dogs in the Frenchman River valley and adjacent uplands in southern Saskatchewan, primarily in the West Block of Grasslands National Park (GNP; 49° 07'N 107° 25'W). There are 22 prairie dog colonies in the area, 13 of which occur within the existing boundary of GNP. I study prairie dogs at 10 different colonies, which I determined to be reasonably representative of the overall Canadian population in terms of colony size, elevation, aspect, slope, and other habitat characteristics (Canadian Great Plains Research Center unpubl. data). I focus my trap efforts in the spring (April to June) and autumn (August to October) to facilitate seasonal comparisons and for attachment of radio-collars before winter.

I use standard methods to catch and handle prairie dogs (Hoogland 1997, 1995). I set mesh live traps (20 x 20 x 40 cm, model 202 single door collapsible; Tomahawk Live Trap, Tomahawk, Wisconsin) in the early morning and I check the traps at least every 2 hours. The traps are typically set near prairie dog burrow entrances and anchored to the ground using steel stakes. I bait the traps with a mixture of peanut butter and molasses and I pre-bait the traps for 3 d to allow individuals to become acquainted with the traps. When animals are caught, I carry the traps to a location 20 m away from the colony edge where I process the prairie dogs. The traps are carefully labeled to ensure that individuals are returned to their exact capture location.

I record the following data from each prairie dog: body mass, neck circumference, zygomatic breadth, forearm length, tibia length, total length, tail length, gender, reproductive status, age class, and parasites.

Body mass is determined by weighing the prairie dogs in a handling bag using a spring-scale.

DISCUSSION

I hypothesize that the northernmost populations of kangaroo rats and prairie dogs share important characteristics, despite their different natural histories, phylogenies and life history 'strategies'. Preliminary, intraspecific analyses (Gummer 1997b) indicate that some life history traits (e.g., longevity, sexual maturity, timing of reproduction) and physiological traits (e.g., body size, fat reserves, hibernation abilities) of northernmost populations vary predictably from those of more southern conspecifics.

Do we need to invest in intense, population specific study of every distinct population of every species of concern to support appropriate management regimes? While this approach would be ideal, population specific studies of every population would surely be financially and logistically impossible. Rather than pursue only population specific research, I suggest that we determine common considerations for populations that are representative of different types of animals in particular ecological circumstances.

For example, we know that many peripheral populations are considered rare or endangered by government organizations. Given the probable importance of intraspecific biodiversity to species' long-term persistence (Hughes et al. 1997, Myers 1997), and therefore to overall ecosystem integrity, we are fortunate that peripheral populations are flagged as conservation priorities. Instead of proceeding with only population specific studies of distinct populations to answer questions such as "How do the northernmost kangaroo rats differ from southern conspecifics?", I encourage conservation biologists to consider as a more realistic and productive context: "How does peripheral occurrence potentially affect different types of animals?"

Northernmost populations of widely distributed (e.g., Great Plains) species may indeed have shorter lifespans, more rapid reproduction, larger bodies and/or fat reserves, harsh microclimates, and unique thermoregulatory strategies (e.g., hibernation) compared to core populations. These variables are critical parameters in wildlife models; however, one common cost-cutting approach is to assume that a population of a species shares such traits with other populations of the same species. I hope that my ongoing research will lend insight into the overall effects of peripheral occurrence. We need to improve our management strategies for distinct populations and we probably cannot study them all. A better understanding of the geographic basis for intraspecific biodiversity should provide a good knowledge base for animal, population, and habitat models, especially sensitivity analyses. These data and models should assist with the assembly of appropriate management plans for distinct populations of wildlife at risk.

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SASKATCHEWAN PRAIRIE FALCONS: POPULATION TRENDS AND INFLUENCES

John Hanbidge
Box 163 RR #5, Saskatoon, Saskatchewan

W.J. Patrick Thompson
Box 234, Clavet, Saskatchewan

Abstract: Prairie falcons (*Falco mexicanus*) have been periodically studied in Saskatchewan since 1958. There has been no consistent method of data collection over the years, but enough data exist to graph trends and draw some general conclusions about the overall health of the population. There are two distinct natal areas in the province comprising the Missouri River drainage basin and the South Saskatchewan River drainage basin. Each appears to show stable population trends over time. Given the reported trends in some grassland bird populations, it would be prudent to monitor the prairie falcon population in a consistent ongoing manner.

The yearly fluctuations in prairie falcon population can be attributed to both environmental and human influences. Factors which have been investigated include: weather, prey base, nest site availability, migration patterns and harvest. Nest site availability is the variable that can be most easily manipulated, with the potential of having a positive effect on the population. With the exception of harvest, all other factors are beyond our control.

INTRODUCTION

Prairie falcons (*Falco mexicanus*) are the most common of the large falcons in Saskatchewan. The breeding population is restricted to certain geographical areas and thus their numbers have never been large. With the exception of a few years of extensive monitoring in the late 1970s, and again in the late 1980s and early 1990s, the population has been haphazardly monitored by bird banders, falconers and biologists since 1958. When these available data are compiled they provide an overall view of the population and show to some extent some long-term trends.

The breeding habitat of prairie falcons in Saskatchewan is segregated geographically into two main areas. The first encompasses the drainages from the Big Muddy Valley west to the Cypress Hills and south to the United States border. The second includes that portion of the South Saskatchewan River (SSR) from Cutbank to the Alberta border. Prairies nest in dirt holes found in the cliffs and cutbanks along these drainage areas. The number of nest holes available may be a limiting factor for the Saskatchewan populations.

Richard Fyfe and members of the Saskatchewan Falconry Association (SFA) began searching the Big Muddy area and the SSR for prairie falcons in 1958 (Fyfe 1958). The Canadian Wildlife Service (CWS) surveyed the SSR (Fyfe et al. 1969, 1972) and the Big Muddy Valley consistently from 1968 to 1972 when there was concern that all falcon populations were threatened by DDT contamination. It appears that the search effort in those years was reasonably consistent and provides a good baseline for population monitoring in those areas. Complete provincial surveys of known prairie falcon nests were conducted in 1974 and 1975 (Oliphant et al. 1976). Mike Gollop found prairies nesting on the Frenchman River near Eastend in 1974 and in 1976 Wayne Harris and the SFA independently discovered substantial populations along small drainages south of the Cypress Hills. Another complete provincial survey of historical nests was made in 1978 including an aerial survey of these new areas referred to as the Missouri drainages. Since then no complete survey of the province has been done in any one year.

Independent surveys of discrete components of the provincial population have been done (C. Stuart Houston, Mike Gollop and Wayne Harris of Saskatchewan Environment and Resource Management, John Hanbidge) in different years with some surveys being more consistent than others. With recent concern expressed over the status of certain segments of the population, more effort to determine numbers of breeding pairs has been undertaken in recent surveys, although production data is incomplete. The combined survey data, however, do give an indication as to what the population is doing.

METHODS

A successful pair is defined in this paper as one which raises at least one young to fledging. The number of occupied sites in any year gives an indication of the number of birds in the breeding population. Occupancy here is defined as a defending pair. True occupancy rates must be obtained early in the breeding season prior to or during egg laying as failed sites often do not have pairs present later in the season. This figure is only available for very few years for specific areas and therefore is not utilized in this analysis.

The number of successful pairs does not necessarily indicate the status of the overall population, but productivity per successful pair can indicate whether or not there is a general problem with viability. For example, high occupancy and low success in one year would not be considered a problem as the success may be due to unique environmental factors such as late snowfall. High occupancy and low success over many years would indicate a major reproductive problem. As well, consistently low numbers of young per successful pair throughout the breeding range would also indicate a general problem. Therefore, productivity is crucial to any population study. Where productivity data were not available for a region, an average of 2 young per successful pair was assumed.

The Saskatchewan Co-operative Falcon Project holds nest records for the majority of historic prairie eyries in the province of Saskatchewan. These show occupancy and productivity from 1959 to 1978. The remaining information comes from unpublished data collected by S.E.R.M. (Mike Gollop, W. Harris, Jane Jenkins), S.F.A. (J. Hanbidge, Patrick Thompson) and S. Houston. Long-term studies of peregrine falcon (*Falco peregrinus*) populations (Court et al. 1988) show that one visit to the eyrie late in a season for banding will give a measure of successful pairs, but will not reflect the actual size of the breeding population. It also shows that surveys done only periodically may also skew the data if the results are from a particularly good or bad breeding year. For example in 1995 a complete survey detected 26 territorial pairs of which 19 layed eggs, 11 hatched young and 9 fledged young; productivity was affected by a late season snowstorm (R. Johnston pers comm.).

RESULTS

Figures 1 and 2 show the combined data from all sources. Mike Gollop studied populations in the Missouri drainages and made several trips to the same eyries in certain years so his data (1978-1996) are most complete. The last complete survey of known historic eyries in Saskatchewan was done in 1978 (Jane Jenkins

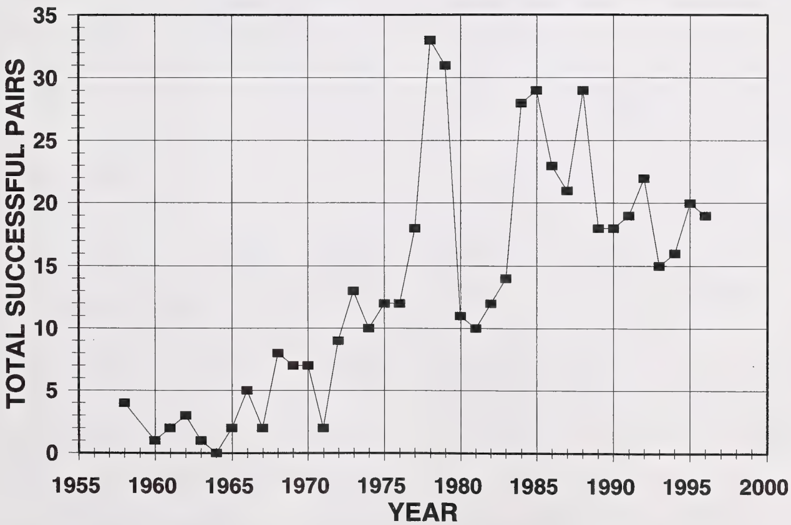

Figure 1. Total number of prairie falcon pairs which successfully fledged young, Saskatchewan, 1958-1996.

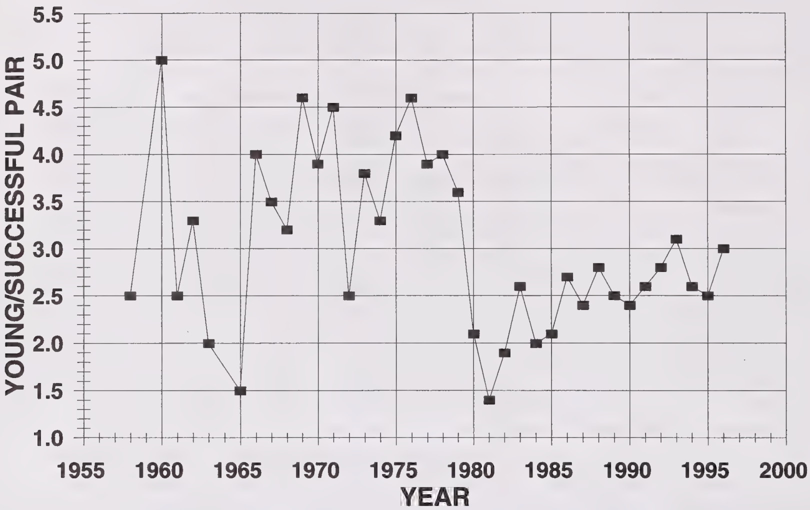

Figure 2. Number of young produced per successful prairie falcon pair, Saskatchewan, 1958-1996.

unpublished 1979). Not unexpectedly this is the year of greatest success and young produced (Figures 1, 2). The best recent data for successful pairs cover 1992 to 1996 when SERM (Wayne Harris and Mike Gollop) consistently covered the southwest corner of the province and Houston surveyed the same 19 eyries along the SSR. Unfortunately the production data is missing for much of the southwest so two young per occupied site are assumed.

Firm conclusions cannot be drawn from these data but it appears that the prairie falcon population on the whole in Saskatchewan is stable and production is at acceptable levels. The replacement standard for prairies is two young per pair (Runde 1987) and in Saskatchewan production is 3.25 young per pair. There are some regional concerns with numbers of successful pairs in the Big Muddy Valley, Twelve Mile Lake and some southwestern creeks of the Missouri drainage, but it is unclear if this is due to poor reproduction, isolated environmental impact or some other factors.

The yearly fluctuations in the prairie falcon population can be attributed to many things. Factors which have been investigated include: land use surrounding the nest sites, prey-base, human intervention, weather, and movement between populations.

The land use around the nest sites in the SSR has changed very little since the peak population period of the 1970s (Oliphant et al. 1976). This was determined by comparison of air photos from the late 1960s with air photos taken in the early 1990s (National Air Photo Archive, Ottawa, Ontario; Central Survey and Mapping, Regina, Saskatchewan). An area 10 kilometres on either side of the river adjacent to known nest sites was analyzed comparing the amount of pastureland and cropland in the two periods. It was found that there was a decrease in pastureland along the river of 38 square kilometres or 1.9% over the last twenty years. Unfortunately the analysis of the air photos does not show range condition which may affect abundance of prey species. By contrast, in the Big Muddy Badlands, there has been a dramatic breaking of pastureland both in the valley floor and up to the edge of the clifftops on the tableland.

It was postulated by Fyfe that a decline in the population of raptors with primarily avian diets was due to insecticides (Fyfe et al. 1969). In 1975 (Oliphant et al. 1976) a study of prey remains indicated that the prairie falcons along the SSR had a diet that was primarily avian. The prey species in order of highest frequency were as follows: ducks, western meadowlarks, blackbirds, northern flickers and brown thrashers. Another population of prairie falcons found along Battle Creek in the Missouri drainage basin of southwest Saskatchewan was studied by J. Jenkins in 1979 and 1980 (the author's name at the time of the study was J. Gollop). In this unpublished study Jenkins found that the prey base for that prairie falcon population was almost completely avian (Gollop 1981). These two areas contrast sharply with the Big Muddy Badlands where the prairie falcon's chief prey is the Richardson's ground squirrel (Rafuse pers. comm., Fyfe 1969). Downes has documented a decline in prairie passerine numbers (Downes 1994) and this may ultimately affect prairie falcon breeding success. Similarly the decline in ground squirrel numbers due to land use changes may be affecting prairie falcon numbers in the Big Muddy area.

The factor of human intervention has played a role in prairie falcon populations throughout the province. Prairies have been utilized for falconry since 1958 in Saskatchewan. These birds were harvested from eyries prior to fledging. During the 1970s there were fourteen young falcons harvested from the South Saskatchewan River and one from the Big Muddy Valley (Guthormson, Thompson and Bush, pers. comm.). There was no apparent negative impact and in fact the population reached its peak during this time. It has been shown that removal of young falcons increases fledgling survival of the remaining young (Conway et al. 1995) and is therefore beneficial to the breeding population.

From 1972 to 1976 another type of human intervention occurred. Thirty-one new nest holes were dug in the SSR (Oliphant et al. 1976) and twelve in the Big Muddy by members of the SFA. Prior to this time the only known nest construction was by Armbruster and Hodson in 1969 in the Big Muddy area (Rafuse, pers. comm.). It is postulated that construction of these nest sites was an important factor in the subsequent increase in numbers of young and occupied nest sites from 1974 to 1978. The figures indicate a rise in occupied sites during this time frame most of which is the result of an increased survey area but some of which may be in response to these interventions. As a management tool nest hole construction could have a positive influence in areas of low breeding numbers.

Between 1980 and 1996 there were a total of eleven artificial nest holes constructed by Houston, Miller, Gerard, Hanbidge and Rafuse. Along the South Saskatchewan five holes were constructed by Houston and Miller (pers. comm.) and three were constructed by Gerard and Hanbidge. Three other nest holes were dug in the Big Muddy Badlands by Bob Rafuse (pers. comm.). Naturally occurring nest holes usually require considerable runoff to form. The winters in the past number of years have been very mild with very little snow cover (Environment Canada Precipitation Statistics) consequently there have been few new natural holes created. Old sites are continually lost due to slumping.

Weather is an important factor in determining annual productivity. There are three specific references in the nest site data for the Big Muddy area where late spring snow storms were responsible for nest site failure. Because prairies are on territory and begin egg-laying in April they can be impacted dramatically by early spring snow storms. Any prolonged snow can cause chilling of the eggs and abandonment.

Migration patterns may influence the population through mixing and recruitment of birds from other populations. Mixing is evident from band recoveries (Schmutz et al. 1991) which show a clear migration of birds into Saskatchewan from Alberta. Houston (Figure 3) analyzed prairie falcon recoveries in Saskatchewan which also show movements into the province from as far away as California. The data suggest these are mostly immature birds, but several breeding birds immigrated from Alberta.

In conclusion it seems that the population of prairie falcons in Saskatchewan may be stable. However, given the concerns about all raptors in the prairie grassland ecosystem it is prudent that long-term consistent monitoring of sample breeding areas be undertaken. This

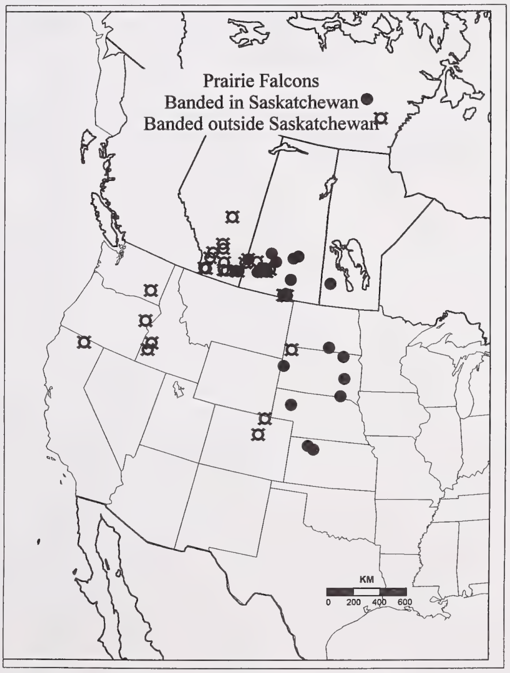

Figure 3. Prairie falcon band recoveries for Saskatchewan (compiled by C. Stuart Houston, 1998).

sampling should include early occupied sites, nest success and production. Perhaps a management plan including harvest and nest site construction could be implemented for areas of concern.

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We would like to thank C.Stuart Houston for the use of his unpublished data and maps dealing with prairie falcons. Similar data was provided by Mike Gollop and Wayne Harris of SERM. We would like to thank Rick Espie and Kelly Black for their work on the graphs used in this article. We would like to thank Greg Rutten for his work on the air photo analysis of the South Saskatchewan River.

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IN SEARCH OF WINTERING BURROWING OWLS IN TEXAS

Geoff Holroyd and Helen Trefry
Canadian Wildlife Service, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3

Jason Duxbury and Troy Willicome
University of Alberta, Edmonton, Alberta

Kort Clayton
Department of Biology, 112 Science Place, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5E2

Abstract: We do not know where the burrowing owls that breed in Canada and are declining in number, spend the winter. Until this winter, there has never been a winter recovery of a Canada-banded burrowing owl. In November/December 1997, JD spent 40 hours flying over south Texas in a Cessna fixed-wing aircraft outfitted with paired antennae and a scanning receiver. Signals were detected from one frequency of 10 that were used in September in Saskatchewan on burrowing owls. The signal was located 90 km southwest of San Antonio on 5 of 6 flights over the area. The owl could not be found on the ground and we cannot fully discount other sources of the signal. However, the signal was probably from a burrowing owl that was outfitted with a transmitter near Moose Jaw, Saskatchewan in September by KC. In January 1998, GH and HT were shown a slide of a burrowing owl with two red plastic bands on the left leg. The style of plastic band and writing on the aluminum band indicate that the owl was banded in southern Saskatchewan in 1996 by TW. These two records confirm that at least some burrowing owls that breed in Canada winter in Texas.

TEN-YEAR CYCLE OF THE GREAT HORNED OWL

C. Stuart Houston
University of Saskatchewan

Abstract: The great horned owl, large, powerful, and long-lived, is justly famous for its strength and aggressiveness, adaptability, exceptionally opportunistic diet, and impressive flexibility in habitat and nest site selection. Threatened it is not.

An intensive program from 1957-1997 resulted in banding of 6912 nestling great horned owls in central Saskatchewan. There have been 541 recoveries to date. Individual owls, at 13 years and at 20 years 8 months, each held the North American longevity record for a year or more. Other interesting information has resulted.

Reproductive success in aspen parkland is cyclical and roughly coincident with the 10-year cycle of the snowshoe hare. Nearly all owls nest in peak years, some raise four young, and they fledge an average of 2.5 young per successful nest. In low hare years, most owls move out (numbers increase in grassland areas), only about half of the remaining pairs nest, and productivity drops to 1.6 young per successful nest.

Particularly when prey becomes scarce, many adults and young move up to 1000 km in a consistent south-easterly direction in fall and winter to the Dakotas, Minnesota, Iowa, Nebraska and Kansas

EFFECTS OF CATTLE GRAZING ON BIRD COMMUNITIES IN COTTONWOOD FORESTS ALONG THE OLDMAN RIVER, ALBERTA

T. Andrew Hurly

Department of Biological Sciences, University of Lethbridge, Lethbridge, Alberta, T1K 3M4

Elizabeth J. Saunders

City Of Lethbridge, 910 - 4th Avenue South, Lethbridge, Alberta, T1J 0P6

Lorne A. Fitch

Natural Resources Service, Alberta Environmental Protection, 2nd Floor YPM Place, 530 8th St. S. Lethbridge, Alberta, TIJ 2J8

Abstract: To assess the impact of cattle grazing on bird communities in riparian forests, we censused bird populations and habitat characteristics in nine sites along the Oldman River between Fort Macleod and Lethbridge, AB. Sites were classified as experiencing High, Medium, or Nil levels of grazing by cattle. The complexity of avian community structure, as measured by species diversity and number of individuals, decreased progressively with increased grazing level. Similarly, plant community complexity decreased with increased grazing level. We conclude that cattle grazing in riparian zones reduces vegetation structure which, in turn, decreases avian community structure. The impacts on birds are most evident in terms of the number of individuals supported rather than in the number of species present. To better manage grazing in riparian zones, we require further information on which vegetation features are important in supporting healthy avian communities.

INTRODUCTION

Riparian zones are ecologically important regions of the prairie environment in North America. The relatively lush vegetation in these habitats provides water, food and cover for many species of animals. The complex vegetation communities lead to complex animal communities, both invertebrate and vertebrate. It is not surprising then that cattle too are attracted to riparian zones for food, water, and shelter. Use of riparian zones by cattle ranges from 5 - 30 times the intensity of use expected on the basis of land area alone (Clary and Medin 1990). Unfortunately, the concentration of cattle in these rare and restricted zones can cause considerable damage. Given the magnitude of the cattle industry in southern Alberta, and its continued growth, it is essential to determine the degree to which cattle grazing impacts on the vegetation and animal communities in riparian zones. Such knowledge will help us develop policies that provide an appropriate balance between economic and environmental benefits of land use.

In western North America cottonwood forests support avian communities that are far greater in density and species richness than are communities in surrounding uplands (Saunders 1988, Strong and Bock 1990). Vegetation and bird communities have been studied at the Bar-U Ranch National Historical site in southern Alberta. To date, results suggest that bird species richness and density are reduced in heavily grazed sites compared to lightly grazed sites (Wershler and Smith 1995). A pilot study in the Lethbridge area compared bird communities in three riparian sites which had experienced no, moderate, and heavy grazing. Again, bird communities appeared to be impacted by grazing intensity (Hurly and Saunders 1997).

Here we present the results of a study involving nine riparian sites in the Lethbridge region of southern Alberta. Three sites have experienced little or no grazing in the past 15 years. Three have experienced moderate grazing, and two have experienced heavy grazing. The last site was a golf course, which was included in the study for two reasons. First, a golf course represents an extreme form of "mechanical" grazing in which grasses, and perhaps forbs, are maintained in high density and healthy condition, but at very reduced stature. Trees are also maintained in excellent health, but shrub or woody-plant growth is discouraged. Second, people sometimes argue that golf courses are environmentally friendly and "natural" in that they provide an abundance of trees and grass. Here we include the golf course as a heavily grazed site in which we can assess the health of the avian community.

METHODS

The study sites were nine riparian cottonwood stands along the Oldman River between Ft. Macleod and Lethbridge in south-western Alberta (Figure 1). Each site was classified as experiencing one of three levels of grazing: Nil, Medium, or High. The Nil sites were the Ft. Macleod River Valley Wilderness Park, and the Nature Reserve and Pavan Park in Lethbridge, none of which had been grazed for at least 15 years. The Medium sites were Mc, Kr, and AD, sites which had experienced moderate levels of grazing according to the information available to us. For example, the 45 acre Mc site experienced 13 cow-calf units for approximately 4 months annually. The High sites were Se, Cottonwood Park (Cw), and a golf course (Gf), all of which experience heavy grazing or mechanical disturbance. For example, until 1996 a 200 acre site including Cottonwood Park experienced 60 cow-calf units for approximately 7 months annually.

Bird Sampling

We used a fixed-point count method to survey bird communities (Bibby et al. 1992). Within each site we established four circular plots 50 m in radius (Figure 1). A census of a site involved an observer (A. Hurly or E. Saunders) standing at the centre of the plot and mapping the locations of each bird seen or heard for a period of 15 min. During the census, and afterward, the observer grouped observations that likely represented a single individual or a breeding pair. The four plots within a site were sampled sequentially within the period starting one half hour before dawn to one and a half hours after dawn. Each site was sampled first during the period 8 - 22 June, 1997, and then during the period 22 June - 4 July, 1997.

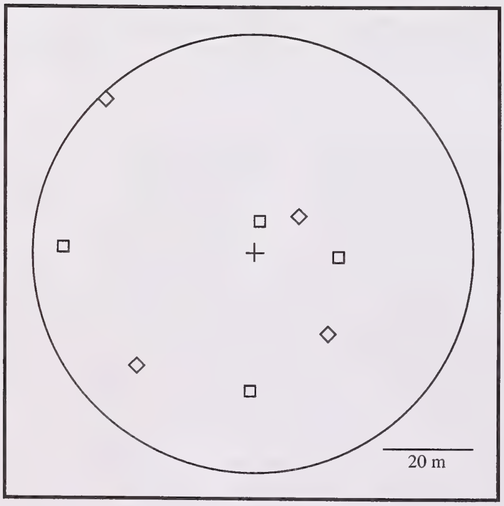

Figure 1. Sampling plot 100 m in diameter in which birds were surveyed. Plant surveys occurred in the eight 2 x 2 m subplots.

Vegetation Sampling

Vegetation was assessed within the bird plots during July and August 1997 using methods modified from Downing (1995) and Hurly and Saunders (1997). We established eight 2x2 m vegetation sampling plots in a spiral at distances of 6, 12, 18, 24, 30, 36, 42, and 48 m from the centre of the plot (Figure 1). Within each plot we identified the five most common species of forbs and grasses and estimated the percent cover and average height for both forbs and grasses, as well as the percent cover bare ground. We also identified all species of shrubs and assessed percent cover of shrubs 0.5 - 1 m in height.

Data were averaged across vegetation plots and then across circular plots to provide mean values for each site.

Statistics

Data were analysed using one-way ANOVAs to examine for variation across the three levels of grazing High, Medium, and Nil, with 3 sites in each level. Subsequent tests between means were conducted using the Fisher's PLSD *a posteriori* tests. Statistical significance was set at a = 0.05, but relevant trends are also reported.

RESULTS

Bird Communities

The effects of grazing on bird communities can be examined in terms of both species richness and numbers of individuals. There was no clear effect of grazing level on the number of species observed in each site although the trend of decreasing richness with increased grazing was in the predicted direction ($F_{2,6} = 2.40$, $p = 0.172$; Figure 2a). There was however, a strong effect on the number of individuals recorded ($F_{2,6} = 8.31$, $p = 0.019$; Figure 2b) in that the high grazing sites supported only about half of the individuals found in the ungrazed sites.

The number of species and the number of individuals can be examined together by calculating a species diversity index. We used the Shannon-Wiener Index in which high numerical scores indicate high species

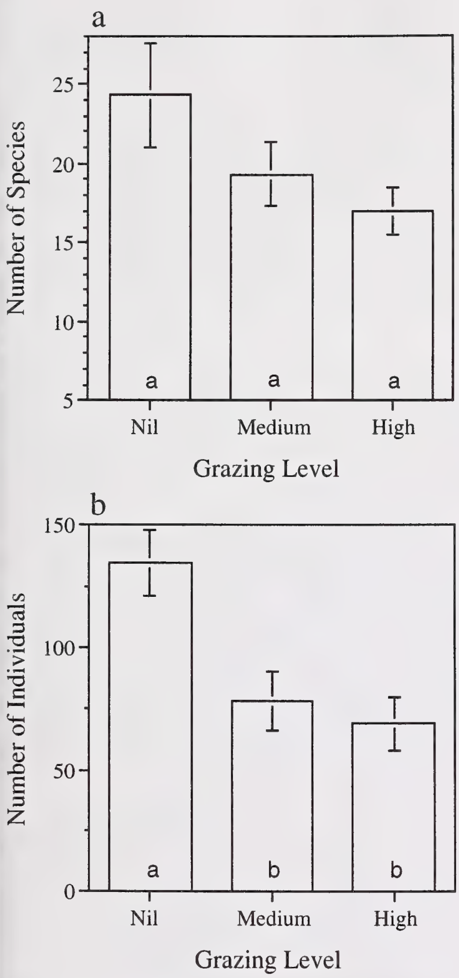

Figure 2. Mean (±SE) number of (a) bird species and (b) individuals recorded in the three sites for each grazing level. Grazing levels with different letters (a and b) differ significantly by Fisher's PLSD tests, $p < 0.05$.

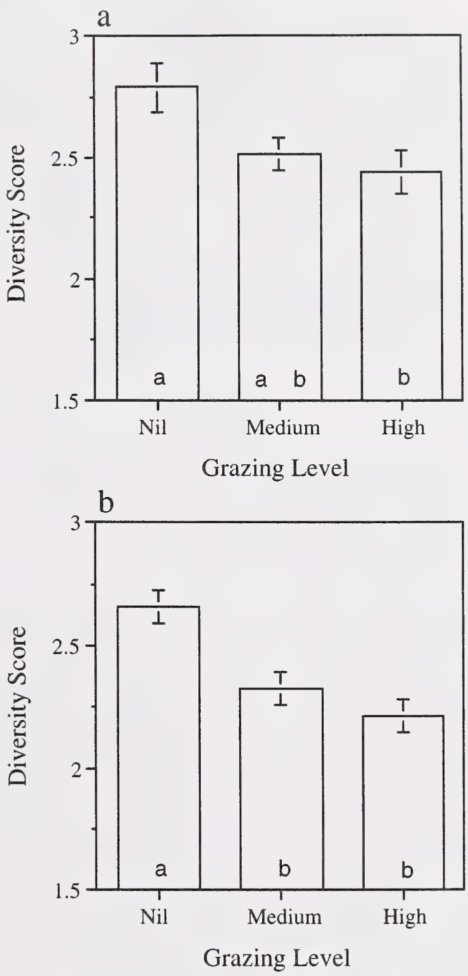

Figure 3. Mean (±SE) species diversity score (Shannon-Wiener Index) for (a) all bird species and (b) native bird species recorded in the three sites for each grazing level. Grazing levels with different letters (a and b) differ significantly by Fisher's PLSD tests, $p < 0.05$.

diversity (i.e. many species are present, each represented by several individuals).

$$\text{Diversity} = -\sum_{i=1}^{N} p_i \log_e p_i$$

Where N is the number of species and p_i is the number of individuals of the i^{th} species.

The species diversity scores decreased with increased grazing ($F_{2,6} = 4.49$, $p = 0.064$; Figure 3a) with significant differences between the Nil and the High levels (Fisher's PLSD, $p = 0.029$). Elimination of house sparrows and European starlings, non-native species, from the analysis revealed a strong effect of grazing level on species diversity ($F_{2,6} = 11.49$, $p = 0.009$; Figure 3b).

Removing house sparrows and European starlings from the analyses did not influence the results in terms

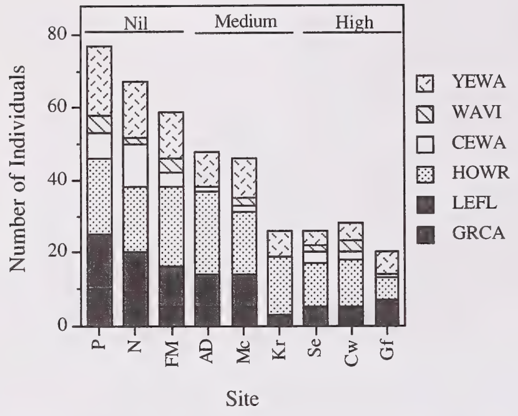

Figure 4. Number of individuals of six common riparian bird species found in each of the study sites (yellow warbler, warbling vireo, cedar waxwing, house wren, least flycatcher, gray catbird). Nil, Medium and High refer to the grazing levels.

of number of species ($F_{2,6} = 2.49$, $p = 0.163$) or number of individuals ($F_{2,6} = 13.90$, $p = 0.006$).

It is possible that the differences observed above are influenced by different species preferring sites with different grazing levels. To compare bird communities across grazing levels using a common currency we selected six species typically found in cottonwood riparian zones in this region: yellow warbler, warbling vireo, cedar waxwing, house wren, least flycatcher, gray catbird. The total number of individuals of these species varied significantly across grazing levels ($F_{2,6} = 17.33$, $p = 0.003$; Figure 4). Thus, even though these species were usually present in most sites, their numbers varied with grazing level.

Plant Communities

The impact of grazing on bird communities is likely moderated through vegetation. Do features of the plant communities vary with grazing level?

The number of shrub species varied significantly with grazing level ($F_{2,6} = 5.34$, $p = 0.047$; Figure 5a) suggesting that grazing reduced shrub species. The number of forb and grass species did not vary with grazing level ($F_{2,6} = 0.152$, $p = 0.862$).

Another measure of disturbance is the number of exotic forb and grass species that have invaded. Overall, the number of forb and grass exotics did not vary significantly with grazing level ($F_{2,6} = 3.30$, $p = 0.108$; Figure 5b), but there were significantly more exotics in the high grazing sites than in the Nil (Fisher's PLSD, $p = 0.042$).

Finally, health of the plant community may be related to shrub density as measured by percentage of ground covered by shrubs up to 1 m from ground level. Percent cover varied significantly with grazing level ($F_{2,6} = 12.57$, $p = 0.007$; Figure 6). The sites which experienced the highest levels of grazing were the most denuded of shrub cover.

Golf Course

It may be argued that the mechanical grazing at the golf course site has made the High grazing level appear to be more severely impacted than it would under cattle grazing. Removing the golf course site from the analyses

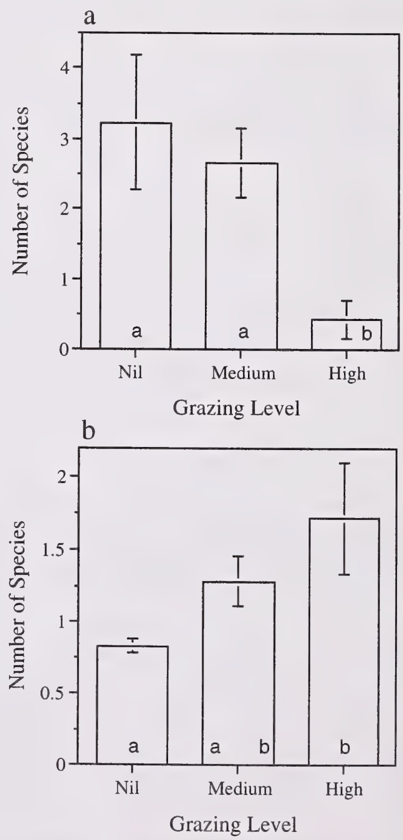

Figure 5. Mean (±SE) number of (a) native shrub species and (b) exotic forb and grass species recorded in the three sites for each grazing level. Grazing levels with different letters (a and b) differ significantly by Fisher's PLSD tests, p < 0.05.

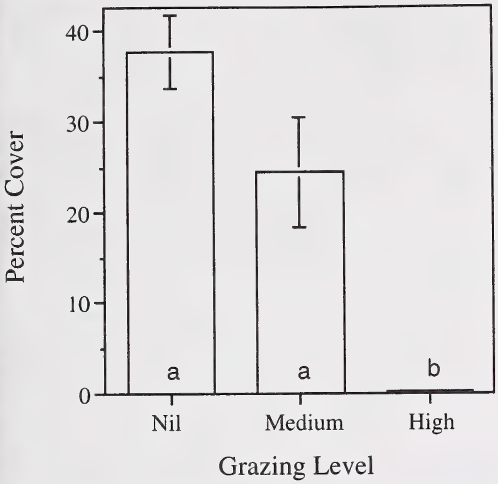

Figure 6. Mean (±SE) percent of ground covered by shrubs to a height of 1 m recorded in the three sites for each grazing level. Grazing levels with different letters (a and b) differ significantly by Fisher's PLSD tests, $p < 0.05$.

caused minor increases or decreases in the F-values of the ANOVA, but had little effect on the results. The golf course site is not introducing significant bias into the analyses.

DISCUSSION

Various measures of avian community structure indicated that community health decreased progressively with increasing levels of cattle grazing. The results were most evident in terms of the number of individuals observed. The number of individuals could be measured as all individuals recorded, or as members of typical riparian species. The species diversity index, which combines both species richness and abundance, also varied significantly with grazing level, especially when non-native species were excluded. Similar results with various measures of avian community structure indicate that the observed effect of grazing level is robust and, therefore, not an artifact of a specific or peculiar measure, method, or site.

Whereas avian community structure decreased progressively with increased grazing level, visual and statistical analyses suggest that the High and Medium sites were more similar to each other than to the Nil site (Figures 2 and 3). Thus, even moderate grazing may have relatively severe impacts on avian communities as demonstrated also by Taylor (1986). This conclusion should be tempered with the caveat that our levels of grazing are not clearly defined with quantitative data. That is, the grazing categories are arranged on a reliable ordinal scale, but we do not have clear measures of the intervals between them. Such quantitative measures of grazing intensity would require tight experimental control beyond that which we could reasonably expect from local ranchers.

Cattle grazing does not likely have a direct effect on avian communities. Rather, grazing influences the vegetation community which influences the avian community. It is clear that the health of the vegetation community decreased with grazing level. Grazing seemed to impact shrubs more than forbs and grasses, in terms of both number of species (Figure 5a) and vertical structure (Figure 6). Reducing shrubs may allow for the invasion of exotic forbs and grasses (Figure 5b).

The golf course ranked lowest for every measure of avian community structure. To some degree, the golf course site represents an extreme example of (mechanical) grazing in that it consisted of manicured grass, a low density of very healthy trees, and no shrubs. If this single golf course is at all representative of golf courses in riparian zones, we might conclude that golf courses are not particularly productive habitats for birds. We should however, consider them in the broader context of a riparian or even prairie landscape in which golf courses may play an important role in the mosaic of a complex and patchy habitat.

The negative impact of grazing on vegetation structure, and thus on birds, we observed is generally supported by other studies in riparian zones in the western United States (Taylor 1986, Omart 1996, Ammon and Stacey 1997). Ivey (1994) lists the impacts of grazing on riparian zones as including: reduction of food and cover plants; reduction of nest sites; reduction of woody understory and the reproduction of both shrubs and trees, resulting in even-aged stands and eventual loss of trees; and soil compaction and erosion of the stream bank such that the riparian zone may be lost completely.

Reduction of the woody shrub layers of vegetation is known to reduce avian community structure in many forest systems (MacArthur and MacArthur 1961, Omart and Anderson 1982). Reduced vegetation reduces nest sites (Ivey 1994), increases predation on nests (Ammon and Stacey 1997), and likely reduces the availability of arthropod food (Brush and Stiles 1986). While riparian zones are highly important to birds during the breeding season, they also support some species throughout the winter and are essential as stop-over sites at which neotropical migrants can replenish fat supplies (Omart 1996).

Both theory and empirical studies indicate that natural communities with high biodiversity resist disturbance and recover from disturbance better than communities with low biodiversity (Tilman and Downing 1994). It is impractical to expect the complete exclusion of cattle grazing from riparian zones because they provide so many benefits to cattle. However, to maintain productive riparian zones for both livestock and wildlife we recommend the development and implementation of management practices that maintain biodiversity. Such healthy riparian zones will support limited grazing year after year because they will be resistant to other disturbances such as drought, fire, flood, etc.

Given the degraded state of riparian communities in western North America (Fitch and Adams, this volume), healthy management practices must first focus on the recovery of riparian zones, and then on maintenance of health. Krueger (1995) suggests that riparian communities are highly variable and that we should design specific management plans for specific sites by considering factors such as hydrology, forage palatability, the behaviour of grazers, and the recovery response of plants to grazing. Such approaches may be effective. Sedgwick and Knopf (1987) studied the impact of grazing in riparian zones that had been undisturbed for 30 years. Fall grazing by cattle stocked at 90% of the recommended stocking rate for three successive years produced no apparent impact on populations of six riparian species dependent upon the grass-herb-shrub layers of riparian vegetation.

To develop effective management practices for riparian zones we must quantify the inter-relationships between grazing, vegetation, and wildlife. These biological relationships can then be assessed within the context of the utility of riparian zones to various segments of society.

ACKNOWLEDGMENTS

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MANAGEMENT OF MANITOBA'S TALL GRASS PRAIRIE PRESERVE

Robert E. Jones

Department of Natural Resources, Wildlife Branch, Box 24, 200 Saulteaux Crescent, Winnipeg, Manitoba R3J 3W3

Abstract: Manitoba's Tall Grass Prairie Preserve, located in the area between Tolstoi and Vita, Manitoba, now encompasses 5360 acres (2169 ha). It is located in the aspen parkland tallgrass community which without active management would move toward aspen forest as a normal part of succession. Management efforts have concentrated on two techniques, burning and grazing, both designed to remove the litter layer and reduce brush and tree species, thus enhancing the grasses and forbs of the tallgrass ecosystem. Regular monitoring has continued and includes plants, birds and mammals. Special concern species include the endangered western prairie fringed orchid and small white lady's slipper. Recent expansion of noxious weeds, St. John's wort, leafy spurge, and others is being carefully watched and controlled where possible.

BACKGROUND

In 1987, Karen Johnson suggested that the tallgrass prairie community could be considered endangered in Canada. Even after the considerable efforts applied during the International Biological Programme (IBP), only 60 sites could be found in the true native prairie community, and none were larger than 5 or 6 ha. Several larger sites were found in the Parklands north and east of the true tallgrass prairie communities. Two of these sites were preserved, one at Oak Hammock and the second which later became Winnipeg's Living Prairie Museum. Later in 1987 the Manitoba Naturalists Society initiated a survey to determine the extent of the tallgrass prairie vegetation remaining in this grassland biome.

Joyce and Morgan (1989) described the Manitoba Naturalists Society's Tall-grass Prairie Conservation Project, which was the first systematic inventory of the tallgrass prairie, begun in 1987. In 1989, the study had located less than 150 ha of tallgrass prairie which once covered 252,000 ha in Manitoba.

Latta (1993) presented an update on this program in 1993. She reported that 610 ha of the tallgrass prairie-aspen parkland had been acquired mostly in what is now known as the Tall Grass Prairie Preserve. This acquisition program was continued by the partners of the Critical Wildlife Habitat Program (CWHP).

Presently 5360 acres (2169 ha) have been acquired by the CWHP partners. The lands are held by the Manitoba Naturalists Society, Manitoba Habitat Heritage Corporation, Nature Conservancy of Canada, and the Department of Natural Resources.

THE PRESERVE ADMINISTRATION

The Tall Grass Prairie Preserve is adaptively managed under a memorandum of understanding (MOU) among the seven sponsoring organizations: Manitoba Naturalists Society, World Wildlife Fund Canada, Environment Canada, Nature Conservancy of Canada, Manitoba Habitat Heritage Corporation, Wildlife Habitat Canada and the Manitoba Department of Natural Resources. The MOU establishes a Management Board whose membership consists of representatives of the sponsoring organizations plus two members from the Local Advisory Committee.

Management activities are organized by the Management Committee, a committee of local experts with knowledge of conditions on the preserve itself. In addition the Chair of the Local Advisory Committee is also a member. The Management Committee has the responsibility of seeing that the prairie is maintained for the future in good condition.

The Local Advisory Committee is a group of residents, including agriculturists, business people, museum directors, and housewives, from the Tolstoi, Gardenton, and Stuartburn area, which provides local input to the management of the Preserve. The Local Committee also organizes public events that celebrate the prairie such as the annual "Prairie Day" and the several open house events that bring the public and the management team together for informative discussions of the prairie and its management. The Local Advisory Committee with the assistance of the Management Committee has developed an interpretive program for the Preserve.

INVENTORY STUDIES

The Preserve contains five of the six tallgrass communities defined by the Manitoba Conservation Data Centre (Greenall 1996). Of the five communities it supports only a few samples of big bluestem-prairie dropseed-little bluestem.

Preliminary surveys of the Preserve area, to determine the extent and quality of the prairie were completed in 1993. In July 1994, infrared aerial photographs were taken of the whole area and used to map and sample the plant communities within the prairie. As properties are acquired further sampling is completed to develop a management plan for the property.

Orchids

Orchids and other rare plants are counted and located in special searches during the flowering period. Roadside surveys followed by more detailed counts have resulted in range maps of the extent of the plants on the Preserve and in nearby areas. Monitoring of small white lady's slipper (*Cypripedium candidum*), western prairie fringed orchid (*Platanthera praeclara*), and great plains ladies' tresses (*Spiranthes magnicamporum*) has been conducted annually since 1993 (Davis 1993, 1994; Borkowsky 1995, 1996, 1997a). A status report for the Western Prairie Fringed Orchid was completed in 1992 for the Committee On the Status of Endangered Wildlife In Canada (COSEWIC) (Collicutt 1992), and a recovery plan for this species was completed in 1995 (Davis 1995). Further work on this orchid is being completed by Karen Johnson of the Manitoba Museum.

Birds

Avian surveys started with an inventory of all species present on the Preserve (Davis 1993, 1994; Borkowsky 1995, 1996, 1997a). This has been augmented by point census information (100 m radius) in the grassland tracts (Davis 1994, Borkowsky 1996, 1997a). In 1996 a MAPS (Monitoring Avian Productivity and Survivorship) census unit was established and has been operated for two years. This technique involves capturing and banding birds during the breeding season to determine trends of productivity and survivorship. At this time 155 bird species have been found using the Preserve.

Insects

Surveys of some forms of invertebrates have been initiated by the University of Manitoba's Department of Entomology, and Dr. K.G.A. Hamilton from Agriculture Canada has collected and ranked some of the leafhoppers from the Preserve (Hamilton 1994). Butterflies have been collected and identified (Davis 1994, Borkowski 1996). A total of 48 species has been identified from the Preserve, including some very rare skippers.

MANAGEMENT

Fire

Prescribed burns are an established part of the management of the grasslands in the Prairie Preserve. Both spring and fall burns have been used since 1993 in an attempt to reduce non-native plants and control aspen encroachment. In 1997 at least 700 acres were burned and 900 acres are scheduled for burns in 1998. Long term management prescriptions call for burns every 4 to 5 years.

Grazing

A twice-over rotational grazing system has been used as a demonstration and experimental grazing system (Lahaie 1998), with considerable success in keeping the prairie in good health and improving conditions for rare plant species. Additional short term grazing has been permitted where existing fencing is adequate to contain livestock. Several other cooperators are interested in using Preserve lands as a part of rotational systems they are developing.

Noxious Weeds

Past agricultural use of lands now incorporated in the Preserve has allowed a number of nonnative plants to expand their numbers and affect the native prairie species. Control of leafy spurge (*Euphorbia esula*), St. John's wort (*Hypericum perforatum*), Canada thistle (*Cirsium arvense*), smooth brome (*Bromus inermis*), and sweet clover (*Melilotus officinalis*) is one of the goals of the management of the Preserve. Use of biocontrol agents, hand pulling and limited use of herbicides along roads and fence lines have been tried to manage populations of these weed species.

Endangered and Rare Species

Swengel (1996) has suggested that many prairie butterflies are negatively impacted by fire, and that these effects may persist for 3 to 5 years. This suggested to management staff that fire or other management techniques used to maintain the plant species might affect pollinating insects that are necessary to maintain species such as the endangered orchids on the preserve. A project designed to discover the pollinators of the western prairie fringed orchid and the small white lady's slipper was initiated last season. Two species of sphinx moths

(*Hyles gallii* and *Sphinx drupiferarum*) were confirmed as pollinators of the western prairie fringed orchid (Borkowsky 1997b). Additional information on the pollinators will be secured this year and their susceptibility to management activities evaluated.

INTERPRETIVE AND EDUCATIONAL DEVELOPMENT

In 1994 the Local Advisory Committee and the Management Committee of Tall Grass Prairie Preserve determined that encouraging Manitoba residents and visitors to stop and visit the prairie would be desirable. A proposal to the Sustainable Development Innovations Fund secured enough funding to complete the development of an interpretive trail, "The Prairie Shore," and a small picnic site. This has been well used by the public since its opening in 1996 at the annual Prairie Day event. A mowed trail approximately 1.6 km in length has 10 stops that describe how the prairie was formed, the early settlement of the area by Ukrainian pioneers, and the endangered species that can be found on the site.

An educational package designed to fit into the curriculum of elementary schools has been prepared by volunteers from the Manitoba Naturalists Society. Funding for its publication has been obtained from the Heritage Grant Program. In 1998, it is hoped that a program coordinator can be secured to introduce this program to schools in the area.

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EXPLAINING STREAM INSECT PATTERNS THROUGH RESOURCE MODELLING: BUILDING ON THE RIVER CONTINUUM CONCEPT

Garland Jonker

Room 337 Biological Sciences, Ecology Division, 2500 University Drive, University of Calgary, Calgary, Alberta T2N 1N4

Abstract: Mean drainage geomorphology is a predictable function of stream size. Since stream biota and resource gradients exist within these geomorphic constrains, Vannote et al. (1980) argue that stream size generally explains patterns of benthic macroinvertebrate composition. Although some studies support this argument, a number of studies find stream size to be a poor predictor of invertebrate composition. The confusion appears to lie in the incongruent spatial and temporal scales of mean drainage geomorphology and the focal scale of benthic macroinvertebrate composition data. To confirm this, the present study demonstrates that stream size is unable to explain the major trends in invertebrate composition among reaches in a Canadian Rocky Mountain drainage system. Further, stream size correlates highly with mean drainage geomorphology, but inconsistently captures geomorphic conditions at the scale of the invertebrate community. Finally, a water temperature model demonstrates that explicitly addressing resources is essential to correcting the scale problem.

THE PRAIRIE ECOSYSTEM SUSTAINABILITY (PECOS) STUDY

Johanne Kristjanson

PECOS Project Team, PECOS c/o Soil Science, 51 Campus Drive Saskatoon, Saskatchewan S7N 5A8

Abstract: The Prairie Ecosystem Sustainability Study is an interdisciplinary community-based study funded by the Eco-Research Program of Environment Canada's Green Plan through the Tri-Council, representing the Medical Research Council (MRC), the Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC). PECOS examines issues related to sustainability in the dry prairie region of southwestern Saskatchewan. Concerns about the capacity of the prairie ecosystem to sustain current agricultural and other land use practices and the health and traditional rural lifestyles of the people in the study area are the foci of this research. Senior researchers from the University of Saskatchewan, the University of Regina, Agriculture and Agri-food Canada, and Environment Canada, residents of the study area, graduate students and postdoctoral associates have spent four years using interdisciplinary community-based approaches to gain insight into the problems, processes and potential for positive changes in the region. In this poster the PECOS project is explained and results of a number of completed elements of the study are presented as they relate to issues of endangered species and prairie conservation.

THE CHALLENGE

There are long standing concerns about the capacity of the prairie ecosystem to sustain agricultural and other land use practices. Concerns are increasing about the sustainability of the health and traditional rural lifestyles of the people and the viability of their communities. Erosion, degradation and exhaustion of soil and reduction of wetlands and wildlife habitat with consequent loss of biodiversity threaten the capacity of the ecosystem to sustain current land use practices. Recurrent drought, persistent economic pressures and increasing farm size have led to rural depopulation and weakening of the community structures that provide essential services. The potential impact of the pervasive use of agricultural chemicals is a growing concern. How, then, do we find the balances necessary to ensure the sustainability of the prairie ecosystem, including its economic and social components?

THE PECOS STUDY

PECOS has aimed to understand the challenges facing the prairie ecosystem and to identify methods of coping with and meeting these challenges through the use of an interdisciplinary and community-based study. Consequently, PECOS is a team of researchers comprised of faculty and graduate students from a variety of academic disciplines at the University of Saskatchewan and the University of Regina, researchers from Agriculture and Agri-Food Canada and Environment Canada and residents of the study area. The study encompasses research into the intertwined issues of human health, the health and sustainability of the land and the sustainability of agriculture and its accompanying rural communities. PECOS has been examining the current conditions and systems and exploring solutions to problems.

THE STUDY AREA

The study area is Agricultural Census Region 3BN in southwestern Saskatchewan which includes 14 rural municipalities around Swift Current. It encompasses an area of 15,177 square kilometres including native prairie, diverse farmlands and a number of rural communities (Figure 1). The human population of the areas was 28,670 in 1991. The study area is located primarily in the Brown soil zone and the mixed grassland ecoregion of the prairie ecozone.

THE RESEARCH QUESTIONS

The research questions being tackled in PECOS can be divided into three main areas: human health, the land and its biota, and agricultural practices and community sustainability. The major research questions being investigated by PECOS are listed below:

Human Health

- observing chronic health problems due to environmental and occupational pesticide exposure

Figure 1. Location of PECOS Study in the Canadian Prairies

- determining whether exposure to herbicides or insecticides is associated with increased acute adverse health effects

Agricultural Practices and Community Sustainability

- economic and environmental consequences of alternative agricultural methods
- socio-economic characteristics for alternative agricultural practices
- history of changing agricultural practice
- environmental ethics of area residents
- farmers rights and responsibilities
- institutional change
- seniors and their communities
- youth and their futures in rural communities
- the evolution of communities during the past 30 years
- identifying the determinants of community sustainability

The Health of the Land and its Biota

- landscape, ecosystem and soil development and change
- chemical elements and their potential movement in the soil, water and plant systems in native and farmed land
- biodiversity in elements of the selected plant, bird, and microbial populations
- determining the conditions of the land in the ecological subunits of the ecosystem and proposing alternative and remedial strategies on land where problems are evident

INTERDISCIPLINARITY

The PECOS project includes interdisciplinary elements at all levels of its design and management. Individual student projects were interdisciplinary in focus. A number of larger group projects were included as a part of PECOS which involved team members from a variety of disciplines. The overall structure and integration of the research process and results have also been interdisciplinary.

Each of the twenty-eight graduate students has conducted a research project that is inherently interdisciplinary. One example of such a project is Andrew Mickleborough's research on economic effects of labile organic matter in the soil when continuous cropping rotations are used. Another way in which interdisciplinarity of individual research projects was expressed was through participation of faculty members from other disciplines on student supervisory committees.

PECOS has also included a number of group research projects which involved researchers from a variety of disciplines. The largest of these projects is the group of researchers examining the effects of pesticides on human health. This research project involves researchers from a number of medical disciplines in the project as well as researchers in disciplines such as geology and hydrology. Another example of group research conducted as a part of PECOS is research on endangered species protection involving researchers from agricultural economics, biology, sociology and environmental studies.

The PECOS project as a whole involves faculty and students from across the university campuses. The disciplines of study of members of the research team include: sociology, soil science, animal science, crop science, plant ecology, agricultural economics, biology, environmental studies, Canadian Plains studies, geography, psychology, philosophy, toxicology, geology, applied microbiology, community health, epidemiology, nursing, agricultural extension, pediatrics, pathology and genetics.

COMMUNITY-BASED

PECOS has actively sought involvement of study area residents in all phases of the research. Study area residents have been active in research design, the research process itself and in the publication and reporting of research findings.

Involvement of study area residents in research design has included study area representatives on the management committee of the project and as members of each research focus group. These representatives as well as other members of the rural communities in the study area have been actively involved in the development of questionnaires and research protocols. This enabled researchers to make the research questions relevant to the issues and people of the study area.

Involvement of the study area communities in the research process includes involvement in the data collection process and data analysis. For example, study area residents were hired to conduct some laboratory analyses and to deliver questionnaires. Local knowledge was also sought in other ways, ranging from assistance in locating hawk nesting sites to identifying people to be interviewed, to providing insight as to changes and rare events that have occurred in the ecosystem over time, to providing insight into the feasibility of policy and stewardship options. Residents of the study area were also involved in the qualitative research process of a number of research projects, influencing the subject matter and emphasis of research projects.

One of the most important areas of involvement of study area residents has been in the discussions relating to the form, content and process of publication and reporting of research findings. Community representatives on the project are getting involved in the writing of research papers. The decision to produce a series of papers aimed at a general public audience was also influenced by consultation with study area residents.

PECOS RESEARCH FINDINGS RELATED TO PRAIRIE CONSERVATION AND ENDANGERED SPECIES

Research on the PECOS study is on-going; however, a number of research projects have been completed. The research that has been completed includes findings that are related to the issues discussed at this conference. Highlights of some of the relevant findings are presented below. These highlights are not meant to be inclusive of all relevant research but rather a sampling of findings from those projects already completed.

- The effects of pesticides on human and ecosystem health is a significant concern expressed by study area residents but concern about stress related to farm finances are also important (Macfarlane 1997, Stewart 1997).

- Some trace elements - particularly Cadmium - appear to be elevated in cultivated soils and agricultural crops relative to native prairie. The effects of these increases on ecosystems are unknown. Potential anthropogenic sources of these elements include phosphate fertilizers (Song 1997).

- Hawks rely on a wide agroecosystem and therefore policy aimed at sustaining them must be directed at the whole agroecosystem and must include landowners in policy development (Portman 1997).

- Rare plants are at risk from cultivation, wetland drainage, exotic species invasion, pesticide drift (particularly wetland species) and habitat disturbance (Robson 1997).

- Surface soil macropores do not appear to be a significant risk factor contributing to contamination of water sources by agri-chemicals in the study area (Spewak 1997).

- The adoption of continuous cropping in the Brown soil zone will increase with greater knowledge of economic and soil quality impacts but the effect of this change in practices on other elements of the ecosystem from resulting high rate of herbicide use is not well understood (Mickleborough 1997).

- Farmers play a significant role in defining their own rights and responsibilities. These rights and responsibilities are continuing to change with new information about environmental impacts (Kristjanson 1997).

- Costs of habitat protection and crop destruction by wildlife must be socialized (society must absorb some of the costs) (Abaidoo 1997, Kristjanson 1997).

- Many farmers feel unable or unwilling to maintain sloughs for wildlife in the future, including many of those who indicate that they have left sloughs for wildlife in the past (Abaidoo 1997).

- Few rural young people expect to participate in farm-related occupations. This will result in an export of knowledge of farming and weakening of individual ties to the land including the natural environment (Butler 1998).

- The decline of rural human communities will continue, driven by market forces; however, the impact of changing structure of communities on the natural environment is uncertain (White 1997).

ACKNOWLEDGMENTS

This research is the product of the work of all members of the PECOS study team. Funding for this Project was provided through the Eco-Research Program of Environment Canada's Green Plan and administered by the Tri-Council Secretariat, representing the Medical Research Council (MRC), Natural Sciences and Engineering Research Council (NSERC) and Social Sciences and Humanities Research Council (SSHRC).

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WEED DIVERSITY IN SASKATCHEWAN FARM MANAGEMENT SYSTEMS

J.Y. Leeson and J.W. Sheard

Biology Department, University of Saskatchewan, 112 Science Place, Saskatoon, Saskatchewan S7N 5E2

A.G. Thomas

Agriculture and Agri-Food Canada, Saskatoon Research Branch, 107 Science Place, Saskatoon, Saskatchewan S7N 0X2

Abstract: Farm management systems in Saskatchewan may be defined in terms of crop rotation and chemical input level. Crop rotations vary in complexity from fallow-based through diversified annual-grains to diversified-grain-forage rotation. Chemical input level may be categorized as high, reduced or organic. In this study the impacts of 1) high input, fallow-based, 2) reduced input, fallow-based, 3) organic input, fallow-based, 4) reduced input, diversified annual-grains, 5) reduced input, diversified-grain-forage and 6) organic input, diversified-grain-forage rotations are assessed on weed communities.

Weeds were surveyed on twenty-eight representative farms located throughout Saskatchewan in 1995, 1996 and 1997. Significantly ($P \leq .001$) higher species richness than expected for the surrounding landscape area was associated with the organic input fallow-based, organic input diversified-grain-forage and reduced input diversified-grain-forage rotations. The organic input fallow-based rotation also had significantly ($P \leq .001$) higher total weed density than expected for the surrounding area.

Weed cover and diversity may enhance the functioning of the agroecosystems by regulating pest insect populations, reducing erosion, regulating nutrient cycling and enhancing survival of wildlife. However, it is necessary to weigh the potential benefits of weed diversity against the potential negative impact of high weed densities on crop yield.

INTRODUCTION

In the last half century agronomic practices have changed dramatically, with the intensive use of chemical inputs becoming commonplace (Haas and Streibig 1982). Concern about the long-term environmental and economic consequences of this reliance on chemical inputs has led to increased concern about the sustainability of conventional agriculture practices (Edwards 1989). Crop rotation and reduced chemical usage have been identified as more sustainable farm practices (Reganold et al. 1990, Schaller 1991). Sustainable agricultural systems aim to increase or maintain environmental protection, production, security, viability and acceptability (FAO 1993).

The view of a farm management system as an ecosystem, or agroecosystem, is complementary to the concept of sustainable agriculture. The agroecosystem approach attempts to maintain "the same types of interspecies relationships, nutrient cycling and biodiversity that characterize the natural ecosystem, while respecting the natural carrying capacity of the land"(Anonymous 1990).

Although weeds are generally thought of as a detriment to the sustainability of farm management systems, several benefits may be experienced if weed communities are maintained below economic thresholds (Clements et al. 1994). The preservation of weed diversity within an agricultural setting may increase sustainability by providing environmental services (Altieri 1993). Several studies have linked plant diversity to the regulation of insect pest populations (Bach 1980, Risch et al. 1983, Horton and Capinera 1987, Andow 1992, Altieri 1993). The vegetative cover provided by weeds has many potential advantages that may lead to sustainable agroecosystems. Weed cover may prevent soil erosion by regulating water and wind flow (Mahn 1984, Gilpin et al. 1992, Altieri 1993). Nutrient cycling may also be affected by weeds in terms of nitrogen fixation and decomposed itter (Burton et al. 1992). Species rich plant communiies have been shown to utilize soil nutrients more effecively, resulting in lower loss of soil nitrogen by eaching than less diverse communities (Tilman et al. 996). Altered microclimate due to weed cover has been onnected to higher levels of detritivors (Purvis and Curry 1984). Weed cover has also been linked to ncreased survival of birds (Aebischer and Blake 1994).

In Saskatchewan, farm management systems may be lefined in terms of crop rotation and chemical input evel. Chemical input level may be categorized as high A), reduced (B) or organic (C). A farm is classified as igh input (A) if the fields are treated with pesticides nd fertilizers based on conventional recommendations. Reduced input farms (B) incorporate cultural controls to educe the necessity for chemical inputs. Organic farmers C) manage pest and nutrient levels by non-chemical means. Crop rotations vary in complexity from fallow-based (1) hrough diversified-annual grains (2) to diversified-rain-forage (3). Fallow-based rotations (1) regularly nclude fallow in an annual crop rotation. The diversiied-annual grains rotation (2) is a continuously cropped otation including a variety of annual crops. The diverified-grain-forage rotation (3) includes a perennial forge crop such as alfalfa in rotation with annual crops.

The impacts of six farm management systems with ifferent chemical input levels and crop rotations are ssessed on weed community diversity and density in his study.

IETHODS

A total of six farm management systems are includd in this study (Table 1). These systems are: high input, allow-based (1A), reduced input, fallow-based (1B), rganic, fallow-based (1C), reduced input, diversified-nnual grains (2B), reduced input ,diversified-grain-orage (3B) and organic, diversified-grain-forage (3C).

Twenty-eight farmers who practice the farm systems of interest (Table 1) were selected to participate in this study. The farms were represented in five of Saskatchewan's ecoregions (Figure 1) (Padbury and Acton 1994). On each farm, farm units were identified consisting of groups of three to fifteen fields managed in a similar manner. Five of the farms had two different farm units; therefore, a total of thirty-three farm units were included in the study.

Weed surveys were conducted in 1995, 1996 and 1997 at least two weeks after any post-emergent weed control so that the weed community present reflected the impact of all agronomic management practices typical of each farming system. Forage crops were surveyed prior to the first cut in late June. The weed surveys were completed between the last week in June and the first week of August. Weeds were identified and counted in twenty 0.25 metre square quadrats placed in an inverted W pattern (Thomas 1985) in each seeded field within each farm unit. Generally, the inverted W was positioned fifty paces into the field from both edges at the first corner encountered to avoid biased positioning of the survey within the field (Thomas 1985). If the field was too small to follow the fifty pace standard, the survey was positioned as near to the center of the field as possible.

Average species richness per field and weed density per metre square were calculated for each farm unit across surveyed years. Paired t-tests (Sokal and Rohlf 1995) were carried out between values obtained for each farm unit and average expected values calculated for the surrounding area based on the 1995 Saskatchewan weed survey (Thomas et al. 1996). This removed known variation attributable to location within the province. The surrounding area used to calculate the expected values included the landscape area (Padbury and Acton 1994) within which the farm was positioned and up to five adjacent landscape areas, until at least thirty fields were

able 1. Farm management systems included in the study.

Symbol	# of farms	Farm Management System
1A ◆	7	High input, fallow-based rotation
1B ◈	4	Reduced input, fallow-based rotation
1C ◇	9	Organic input, fallow-based rotation
2B ■	7	Reduced input, diversified annual-grain rotation
3B ▲	3	Reduced input, diversified-grain-forage rotation
3C ∠	3	Organic input, diversified-grain-forage rotation

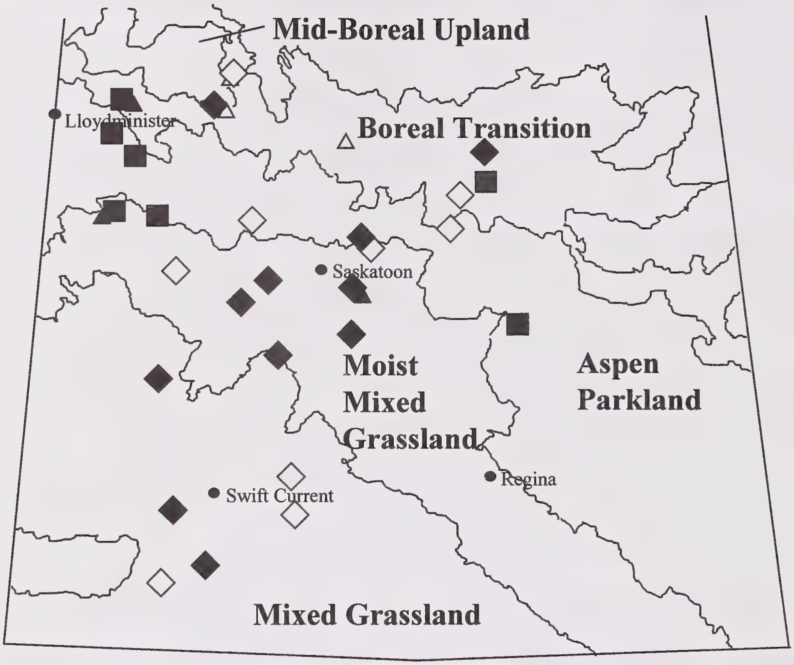

Figure 1. Location of study sites in Saskatchewan ecoregions (Padbury and Acton 1994). Symbols used for farm management systems are in Table 1.

included in the calculation. The fields included in the 1995 Saskatchewan weed survey were farmed using conventional practices (including zero-till) and seeded to the ten most commonly grown annual cereal, oilseed or pulse crops (Thomas et al. 1996). Therefore, organic fields (C) and fields seeded to more diverse crops including forages (3) were excluded from the provincial survey.

RESULTS AND DISCUSSION

Significantly ($P<0.001$) higher species richness than expected was observed in the organic input fallow-based rotation, reduced input diversified-grain-forage rotation and organic input diversified-grain-forage rotation (Figure 2). Although it is generally accepted that diversity enhances the sustainability of ecosystems, it is unclear what level of diversity is necessary for a sustainable system (Baskin 1994). Above an intermediate level species richness, the beneficial impact of each additional species on ecosystem processes tends to decrease (McGrady-Steed et al. 1997). It has been shown that some of the benefits of species richness are present at levels lower than the least diverse farm system (Andow 1992, Bach 1980, Tilman et al. 1996); therefore, many of the benefits of diversity may be present in all the farm management systems studied.

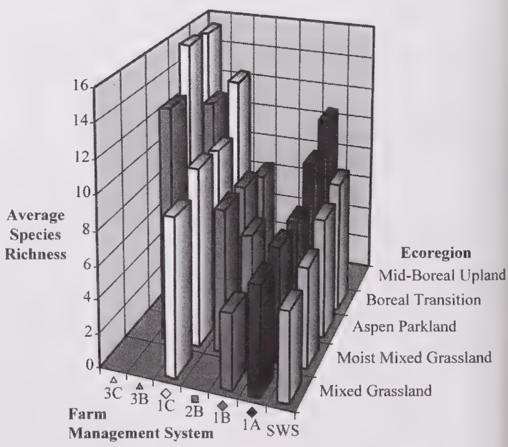

Figure 2. Average weed species richness. Farm management systems are identified by symbols in Table 1. SWS = Saskatchewan weed survey (Thomas et al. 1996).

Significantly (P<0.001) higher weed density than expected was observed in the organic input fallow-based rotation (Figure 3). It is necessary to determine the threshold at which the benefits of weeds are outweighed by the negative impacts of weed pressure on the crop. Each weed species has a different competitive ability making it difficult to establish a threshold for the total density of weeds in multispecies communities (Aldrich 1987). Weed densities as high as 180 plants per metre square have been reported to have no significant effect on wheat yield (Frick 1993). An economic analysis is necessary to determine if any reduction in yield due to weed pressure severely impacts profit margin.

CONCLUSIONS

This study established baseline data illustrating differences in both weed diversity and density associated with Saskatchewan farm management systems. Currently there is no evidence that weed density or diversity in any of the farm management systems are at an unsuitable level. Sustainability implies suitability over time; therefore, inferences about sustainability require an understanding of the rate of change in an agroecosystem. Future monitoring of these sites may enable the detection of any change in weed diversity or density.

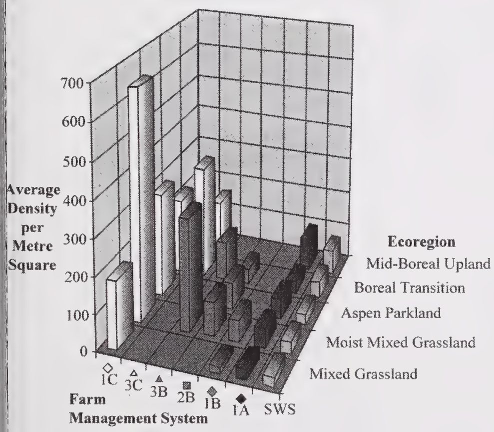

Figure 3. Average density of weeds per metre square. Farm management systems are identified by symbols in Table 1. SWS = Saskatchewan weed survey (Thomas et al. 1996).

ACKNOWLEDGMENT

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THE IMPACT OF PESTICIDES ON HEALTH: PERCEPTIONS OF FARM FAMILIES IN SOUTHWESTERN SASKATCHEWAN

Patricia Macfarlane

University of Saskatchewan, Saskatoon, Saskatchewan

Abstract: Perceptions concerning the use of pesticides vary widely among stakeholders in the agricultural community. In this study, the perceptions of one significant group - farm families - were explored. This study was part of a larger, inter-disciplinary study named the Prairie Ecosystem Study (PECOS) which had the objective of studying the sustainability of the prairie ecosystem. A qualitative research approach was employed to meet the objectives of the study. Members of farm families living in southwestern Saskatchewan with children under the age of 16 years were chosen to participate in the study. Personal, semi-structured interviews were conducted with 11 men and women with ages ranging from 27 to 50 years; 9 were users of pesticides. Generally, views of health, general family health concerns, the use of pesticides, pesticide health concerns, policy, and the importance of the issue, were explored with participants. Results were classified into three main themes labelled health, pesticides, and other issues, and 13 sub-themes. Forty-nine concepts were developed and classified under the themes and sub-themes to which they were related. The concepts and themes developed were ultimately related to the core issues of survival and economics. Overall, findings illustrated that the farm families experienced a dilemma characterized by a desire for an alternative method, a lack of viable alternatives to chemical use, and the economic "need" to use pesticides. Recommendations for further education, the stabilization of farming operations, the industry, and the community, the development of more sustainable agricultural practices, and the enhancement of the political power of farm families are discussed.

NTRODUCTION

Perceptions concerning the use of pesticides vary videly among stakeholders in the agricultural commuity. In this study, the perceptions of one significant roup — farm families — were explored. This study vas part of a larger, interdisciplinary study named the rairie Ecosystem Study (PECOS) which had the objecve of studying the sustainability of the prairie ecosysem. PECOS commissioned about 60 graduate students nd faculties from the two Saskatchewan universities to onduct studies in one region. Three focus groups comrised the interdisciplinary study; one group explored ocioeconomic issues of agriculture and community evelopment, another investigated human health risks ssociated with agriculture, and a third group studied the npact of agricultural activities on the natural environent. Studies were conducted in a region of southwestern askatchewan near the city of Swift Current that correponds to Census Region 3BN.

The purpose of this research was to assess percepons of a sample of adult members of farm families egarding the impact of pesticides in the environment, n their health and their family's health. Farm families ith children under the age of 16 years were sought for this study. This segment of the rural population was selected largely for two reasons. First, they had a critical perspective which had been neglected in previous research on this topic. Second, the knowledge that could be gained from the participants' views as both "farmer" and "parent" was deemed valuable. An understanding of the assumptions and conceptions that farm families hold about pesticide health concerns is crucial to developing a broader understanding of their behavior. Perceptions of farmers are also an important consideration in policy development, which ultimately, is a goal of PECOS. The feelings and opinions of these families should be considered in the process of suggesting ways to maintain and improve a healthy prairie environment. Since the study of the sustainability of the prairie ecosystem is the main objective of PECOS, this research provides a significant contribution. In addition, limited research has been conducted on the perceptions of farmers, and particularly, farm families, regarding pesticide health issues. Farm operators are important stakeholders in the development and implementation of new agricultural practices and their perceptions can provide valuable insight. Note that in this study, the term "pesticides" referred broadly to the range of chemicals utilized in agricultural practices, including pesticides, herbicides, and insecticides.

METHODS

A qualitative approach to the investigation of perceptions was chosen because it permits one to understand meaning in the lives of respondents, provides a holistic approach, and is sensitive to a particular region or people. Specifically, semi-structured interviews were held with adult members of Saskatchewan farm families with children under the age of 16 years living in southern Rural Municipalities (RMs) of the PECOS study region (Census Region 3BN). These RMs can be expected to be similar in context since they share a common soil type, mainly mixed farming practices, and are located approximately an hour from the city of Swift Current. Farm families were defined as persons residing on a farm with at least one adult family member who works the majority of the time operating the farm.

Semi-structured personal interviews were conducted with participants for the purposes of data collection. A general interview guide was developed that served to outline the set of topics discussed with each participant, but it did not force the order or actual wording of questions in advance. This method permitted the exploration of other topics relevant to respondents. Question topics included: views of health, views of pesticides, views of pesticide health impacts, views of precautions, behavior and policy, and the importance of the issue.

The most extensive data collection occurred during July and August, 1996, to avoid interruptions during the farming season and to maximize data collection opportunities. Additional data were sought in January, 1997.

RESULTS

Demographics

Eleven adult farm family members (five women and six men) participated in the study. Their ages ranged from 27 to 50 years (M = 38 years, SD = 6.75 years). All the participants had children under the age of 16 years; the childrens' ages ranged from one year to 24 years (M = 9.8 years, SD = 6 years). All the participants had resided on their farms between 4 and 30 years (M = 15.9 years, SD = 7.82) and all were producing cereal crops. Six of the 11 farms had cattle operations, as well. Two respondents were registered organic farmers, the remaining nine were using pesticides.

Qualitative Analysis

The interview data was analyzed using ATLAS/ti, a computer software program designed to assist in qualitative data analysis. This package offered coding, search and retrieval, memoing, networking, and theory-building techniques that were suitable for the data analysis needs of this study. Meaningful segments of the data (sentences or paragraphs) were assigned codes. All 11 interviews were coded in their entirety. Sixty-eight codes or "concepts" were developed initially. Some concepts were collapsed or renamed ultimately resulting in 49 concepts.

The next step involved organizing the concepts into code families or "categories." Thirteen major categories were established that subsumed all 49 concepts. Some concepts were applicable to more than one category. These 13 categories were further classified into three simple categories (Health, Pesticides, Other Concerns). In addition, two overarching higher-order categories (Economics and Survival) were identified. These two categories are at a more abstract level than the other categories. They underlie many of the relationships among other categories and are interrelated with several concepts. This classification system is represented in the chart in Figure 1. Figure 2 is a graphic illustration of the relationships among the concepts and categories that were discovered in the study.

Health

It is important to note that both organic and non-organic farmers' definitions of health were focussed on issues of diet and fitness. A broader definition of health that was occasionally recognized included a healthy mental state, a supportive health care system, community involvement, or life satisfaction. Health was believed to be within one's control except in the case of genetic disease. Increased awareness and knowledge about health-related issues were believed to be related to an increase in age. Also, a rural lifestyle was deemed a healthy one and it was perceived that it was healthier than living in an urban setting.

The greatest family health concern identified was related to farm accidents. Fear about tainted water supply was also a concern raised. The use of pesticides was raised as a family health issue but it was not viewed as the most important issue. Finally, stress was widely recognized as a health concern among those in the study. Women in this study appeared to be the ones most concerned with the family's health. Women were also identified as encouraging safe farming practices in their husbands.

Ambivalence was expressed by all participants, but less by organic farmers, about the link between pesticide use and health. Some fears relating to short-term

SURVIVAL ECONOMICS

I. HEALTH

Views on Health:	Control Age Stress Definitions of Health Rural Versus Urban Changing Views of Health Media Defining Health
General Health Concerns:	Accidents Stress Importance of Issue Water
Pesticide Health Concerns:	Cancer Blame/Unknown Seasonal Drift Smell Spills (Exposure) Children's Health Environment Long-Term Effects Wildlife Water Gender

II. PESTICIDES

Views of Pesticides:	Defining Pesticides Necessary Fear Desire Dislike Healthiness of Product
Use of Pesticides:	Minimum Use Proof Cost-Benefit Herbicide-Insecticide World Market
Views of Precautions:	Education Gender
Use of Precautions:	Analogy Minimum Use Age
Pesticides/ Precautions:	Doubt Ambiguity Chemical Companies Mistakes of Past Licensing Confidence Biological Controls Horror Stories Dilemma Lack of Control Choice Economics Hopelessness
Views of Alternative Methods:	Biological Controls Healthiness of Product
Policy/ Regulation:	Government Farmer Input Education
Research:	Ambivalence Mistakes in Past Confidence

III. OTHER CONCERNS

Future of Farming:	Hopelessness Lack of Control Stress
Declining Services:	Hopelessness Lack of Control

igure 1. Chart representing conceptual development in analysis.

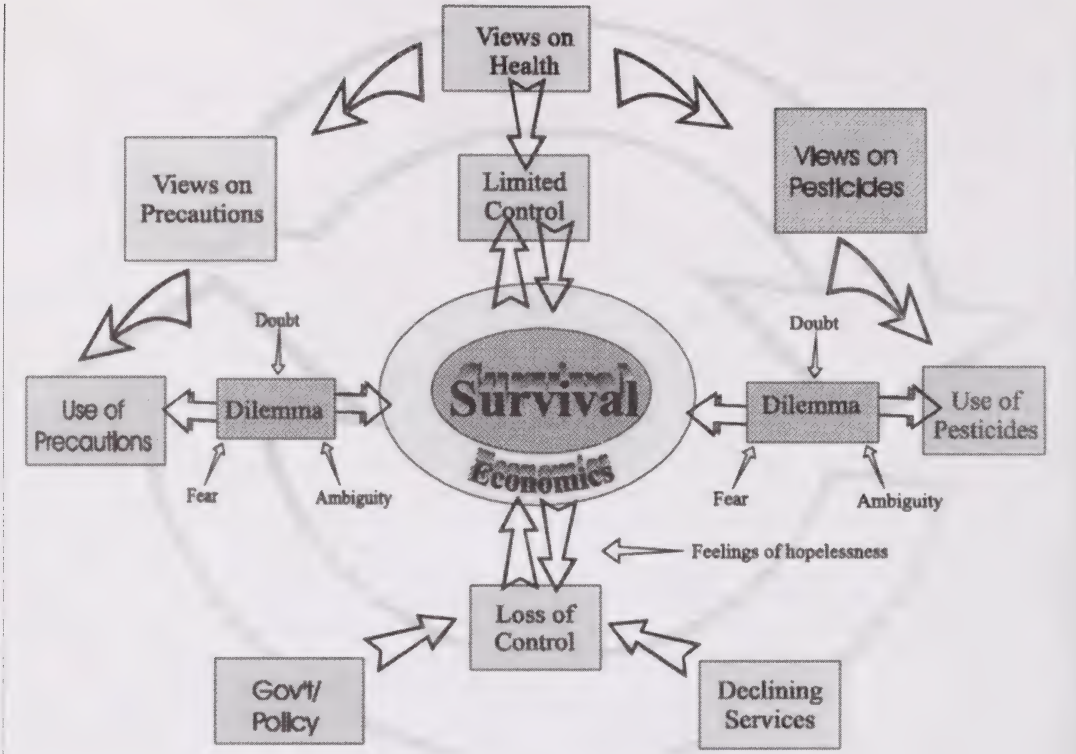

Figure 2. Schematic representation of conceptual linkages in data analysis.

accidental and chronic exposure to chemicals were identified. This health concern was highest during spraying season.

A need for greater education and research about the effects of pesticide use on health was expressed in this study by both organic and non-organic farmers. These findings emphasize a growing dissatisfaction with the current level of knowledge about the benefits and risks of pesticides. Perhaps interdisciplinary studies on the issues relevant to pesticide use can begin to expand upon current knowledge bases while maintaining a holistic perspective.

Pesticides

Pesticides were viewed by non-organic farmers as a "necessity" or "necessary evil" required to maintain financial survival of crops and, ultimately, the farming operation. Although organic farmers did not agree with this statement they understood why they would feel this way.

Non-organic farmers felt that pesticides did not affect the health quality of produce; however, a dislike toward using chemicals, concerns about their impact on environmental and human health, and a desire for an alternative were expressed. The belief that herbicides were less dangerous to use than insecticides was apparent in this study. Pressure to use chemicals was felt from the global market which was perceived to encourage more efficient production.

The use of pesticides, among non-organic farmers in this sample was reported as "minimal" and resorted to only as necessary. Cost-benefit analyses were employed in order to determine the amount of chemical purchased and applied in a given year. Pesticides, in this study, were not viewed to be associated with a low level of risk. The use of herbicides, however, was associated with lower risk than insecticides.

Doubt, fear, and ambiguity were spawned by a lack of confidence in the results of chemical testing done by manufacturers. This lack of confidence was a result of being made aware of mistakes that had been made in the past regarding the safety of chemical products.

Contradictory views about pesticide safety were expressed in this study. It was believed that the government would not allow unsafe products to be marketed; however, there was also a distrust of safety regulations. Ultimately, experiences of being caught in a dilemma — fuelled by a lack of alternatives and an unstable economic situation — were declared. As a result of these factors, feelings of fear, stress, hopelessness, loss of control, and ambivalence were identified.

Precautions were generally viewed with respect and deemed necessary. However, some precautions were perceived to be costly and impractical, and therefore rarely used. Non-use of precautions was perceived by respondents to be related to age or an attitude of invincibility. Women in this study were more likely to endorse the use of precautions and encourage their use by their spouses.

Alternative methods were viewed by conventional farmers to be costly and their produce was not viewed to be any healthier than produce developed using conventional agricultural practices.

Pertaining to policy issues, a negative response was expressed toward the idea of further government regulation of farmers. It was believed that true farmer input has been lacking and is needed in the development of agricultural policies. Greater government regulation directed at chemical manufacturers was desired.

The research conducted on the health risks of pesticides was viewed ambiguously as both credible and unreliable. This ambiguity was related to misjudgements made about the safety of chemicals in the past and the profitability associated with chemical manufacturing which might influence companies to minimize the risks associated with chemical use.

Other Concerns

Other concerns expressed included issues surrounding declines in rural services and the future of farming. The failures of communities to maintain hospitals, businesses, schools, and community organizations were devastating to participants. Concern that farming could not continue much longer in its current form was also raised. These factors resulted in feelings of grief, hopelessness, and loss of control in participants.

Survival and Economics

Two over-arching themes that permeated the results were survival and economics. Survival related to the personal survival of farm family members, the survival of the farming industry, and the survival of a rural way of life or "community" which participants valued. Economic issues were apparent at the local, national, and global level. Economic instability at these levels interacted with several categories that emerged from the data.

Organic Farmers

Two organic farmers were interviewed in order to illuminate the findings of the other nine conventional farm family members interviewed and to determine if alternative explanations for the findings were evident. Organic farmers believed that conventional farmers were brainwashed by chemical companies into using pesticides excessively. This sub-sample believed that conventional farmers lacked knowledge about the benefits of organic farming practices. It was felt that pesticide use by conventional farmers was related to short-term economic survival. Similar attitudes about the need for more education and research into pesticide use and its risks were identified. Increased regulation of pesticides was desired as well. The issues of community deterioration and the belief that conventional farms would not be sustainable in the future were also shared by organic and conventional farmers in this sample. However, organic farmers were optimistic about the sustainability of their method of farming.

Overall, even though the entire sample utilized in this study exhibited a wide range of demographic characteristics (e.g. age, gender, residence), they had similar attitudes towards the issue of pesticide-related health concerns. Particularly, feelings of ambivalence towards the issue of pesticide use was felt — they feared and despised it but at the same time felt it was necessary and useful. These beliefs were subscribed to in varying degrees by different participants. The exploratory and descriptive nature of this study does not permit further analysis of the variations in opinion. However, this aspect of the results could be explored in further research.

Limitations

Some limitations of this study include its narrow focus and limited transferability, timing and weather concerns, and the possibility of "press-release" effects. The study focused on a limited geographic area and the age and types of respondents sought were restricted. However, it is expected that readers were given sufficient detail regarding this restriction in order to independently judge the appropriateness of transferring the analysis to another population.

Timing of the interviews may have also influenced this study's credibility. Poor weather conditions resulted in an exceptionally late seeding and harvest in 1996 that may have influenced responses. Alternatively, some of the hopelessness and lack of control felt by interviewees may be related to a lack of experience with farming. The majority of farmers had been farming between 8 and 24 years. Although this may appear to be a lengthy time, they may not have yet accepted the fluctuations that occur over decades of time that characterize the farming industry.

"Press-release" effects may also be evident in this study, since PECOS began in the area two years prior to this study being conducted. Some respondents expressed concerns about my potential affiliations when their participation in this study was sought. After explaining my affiliations and their right to refuse participation, the potential participants' fears appeared to be allayed and they proceeded to grant permission for an interview. However, it is possible that these concerns held by interviewees influenced their responses to the interview questions.

RECOMMENDATIONS

1. Education about health and pesticide issues is needed.

Respondents were clear in identifying education as a source of motivation for adopting safer agricultural practices when using pesticides. Specifically, a broad definition of health recognizing the wide spectrum of factors contributing to one's mental and physical health should be incorporated into educational programming. Farm families need to receive current and accurate information pertaining to the impacts of pesticides on human and environmental health. Organic farmers sampled felt that more education was needed about the practices and benefits of organic farming. Education about the benefits and proper use of precautions should also be directed at farm family members. Particularly, respondents expressed a desire for practical demonstrations of safety equipment and gear. This education should be physically and financially accessible to all farm operations.

2. Programs which address the stabilization of personal farming operations, the farming industry, and the community should be developed.

Due to the instability of these three major domains, farm families suffer physically and psychologically. Programs aimed at achieving stabilization in these domains will benefit the "health" or "sustainability" of farm families. Mainly, they perceived a necessity to use chemicals to survive while at the same time they feared negative impacts on human and environmental health. They felt limited by economic stability and a lack of available alternatives to adopt safe and healthy agricultural practices. Evaluation of the utility of various options (for example, programs such as NISA, the Net Income Stabilization Account) should be explored in future research involving the farming community.

3. There is a need for agricultural research to be directed toward the development of safer and more viable alternatives to the current pest eradication methods.

This research should involve farmers at all levels, most importantly, during planning and feedback stages. Respondents were critical of current societal values, namely efficiency and profitability, that were driving technological development. They supported a shift in the development of technology that focused more on the development of healthier, more sustainable practices than on efficiency.

4. Political power of farmers should be enhanced by true farmer input into the development of government policies pertaining to agriculture, and specifically, to the issue of pesticides.

Farm families felt that they lacked the political clout to affect changes which have a direct impact on their lives. Increased rural representation in policy- and decision-making processes could return some power to farmers in areas affected by these processes. The involvement of farmers should be sought in the development of solutions to the social, economic, political, and environmental dilemmas that are now plaguing our society. Corporate, academic, and government institutions should form alliances with the farming community to achieve these solutions.

CONCLUSION

This study has contributed to a limited area of literature on the perceptions of farm families toward pesticide health impacts. Furthermore, it provides a unique contribution to an understanding of sustainability. Significant findings such as the ambivalence of participants, the dilemma they experienced, and their overwhelming struggle to survive, formed the basis for my development of the following conclusion.

Ultimately, this study has shown me that farm families' experiences, ways of knowing, and interests have not been adequately represented in political, corporate, or academic arenas. I hope that research utilizing this population continues as farm families' experiences must be given expression. Farm families should be treated as authoritative speakers of their own experience.

An open dialogue must be maintained between those controlling the agriculture industry and the main subjects of that industry. The inclusion of farm families in the development of policy and research agendas pertaining to pesticides and health will contribute to the development of informed solutions to our social and environmental dilemmas.

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I would like to acknowledge the contributions of my thesis co-supervisors, Dr. Nikki Gerrard and Dr. Ron Fisher to this project, and thesis committee members, Dr. Linda McMullen and Gail Remus. The Prairie Ecosystem Study is recognized for the financial assistance that it offered to this project. Finally, and of great importance, gratitude is expressed to all the people who participated in the study. Without the invitation into your homes and your lives, the success of this study would not have been possible.

CROP PRODUCTION SYSTEMS FOR THE CANADIAN PRAIRIES - SOIL BIOTA

O. Olfert, S.M. Boyetchko, S.A. Brandt, and A.G. Thomas

Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, Saskatchewan S7N 0X2

Abstract: Soil microfauna are involved in a number of soil processes such as decomposition of organic matter, nutrient mineralization, regulating micro flora (including plant pathogens) and decomposition of agricultural chemicals. Soil arthropods, especially those found in the soil water, can play a significant role in soil micro-biotic processes. Vesicular-arbuscular mycorrhizal fungi are the most common of all soil fungi that form beneficial associations with approximately 90-95% of all vascular plants. Agricultural practices can have a very significant impact on soil micro-fauna populations. This study was initiated to monitor and assess alternate input and cropping strategies with respect to biodiversity and pest dynamics. The type and spatial distribution of soil arthropods and vesicular-arbuscular mycorrhizal fungi were determined during the first year of establishment of the field site and will continue to be monitored over the next 12-18 years. The direction and rate of change that is occurring in these components will be assessed as a function of the different cropping systems (treatments). These studies are intended to serve as a guide for the development of sustainable cropping systems.

THE PROBLEM

Nearly all of the world's arable land is already involved in some form of production. As a result, increases in production that are required to meet the demands of our increasing population can only come from increased productivity from our current base. The prairie ecosystem is a major contributor to world food production. Arable cropland of the Canadian Prairies is one of the most altered landscapes in North America. Only small remnants of native prairie remain. Profitability and soil degradation are major issues facing farmers in the grassland ecozone of the Canadian Prairies. Producers are encouraged to diversify away from cereal monoculture and to reduce fallow and inputs to address these issues. However, climatic and economic considerations do restrict what can be grown. Alternative production systems are needed to meet the demands for food while preserving the ability of future generations to meet their needs. While some agricultural practices have been evaluated for their short-term impact on production and economics, none have been evaluated for their long-term impact on sustainability. Sustainable land management is defined here as:

> *Sustainable land management combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously: (i) maintain or enhance production/services; (ii) reduce the level of production risk; (iii) protect the potential of natural resources and prevent degradation of soil and water quality; (iv) be economically viable; and (v) be socially acceptable.*
>
> (A.J. Smyth and J. Dumanski 1993)

Evaluation of interactions between the biological, physical and chemical components of agricultural systems is complex. As a result, the design, data collection and evaluation must be based on the collaborative efforts of a multi-disciplinary team of crop, pest, economic and soil scientists. In addition, such evaluations often involve a long-term commitment to monitoring specific components within the agricultural system to determine rate and direction of change over time. The desire to maintain the biological productivity of our agricultural systems has positively influenced the study of the various components that contribute to the quality and health of our prairie soils. Soil biota, such as soil arthropods and mycorrhizae are an inherent component of soil health, which in turn, is the basis of sustainable land management. As a result soil biota have a role to play as indicators of soil health. Indicators are referred to here as measurable traits useful in evaluating systems or environmental processes. It is anticipated that an evaluation framework that includes soil biota will identify attributes that are associated with the respective cropping systems. This, in turn, will contribute to our understanding of the impact of cropping systems on sustainability issues.

THE PURPOSE

This study was initiated to monitor and assess alternate input and cropping strategies based on three levels of production inputs and three levels of cropping diversity. The study will evaluate the different strategies over an 18 year period with respect to (i) biodiversity (ii) pest dynamics (iii) farm profitability (iv) soil quality (v) food safety. This paper describes the evaluations of the soil biota.

METHODS

The 16 ha site is located at the Agriculture and Agri-Food Canada Experimental Farm at Scott, Saskatchewan (52° 22'N; 108° 50'W). Scott is located in the Dark-Brown soil zone; the area is categorized as moist mixed grassland. The experimental framework is based on a matrix of three levels of input use, and three levels of cropping diversity. The three levels of inputs are assigned to main plots in a split-plot factorial design. Large plot size (75m X 40m) is used to preserve input treatment integrity. The input levels are described as:

1. **Organic.** Pest control and nutrient management are based on non-chemical means in an attempt to reproduce the crop management strategies that an organic grower might undertake within the constraints of diversity levels.

2. **Reduced.** Integrated long-term management of pests, nutrients and minimum tillage are used to reduce non-renewable inputs (pesticides, fertilizer, fossil fuels). Chemicals supplement other management practices.

3. **High**. Pesticides and fertilizers are used 'as required' based on pest thresholds and soil tests in a conventional tillage system. Chemical inputs are used to respond to pests and nutrient deficiencies as they arise.

The three levels of cropping diversity are assigned to sub-plots within each main plot to enhance detection of diversity level differences. The levels of cropping diversity follow a six-year rotation and are described as:

1. **Low**. Historic land use patterns of the region are reflected: summerfallow-wheat-wheat-summerfallow-canola-wheat. The organic input treatment would also include a legume green manure as a substitute for summerfallow.

2. **Annual Grains.** A diversity of cereal, oilseed and pulse grains excludes summerfallow: canola-fall rye-pea-barley-flax-wheat.

3. **Grain/Forage.** A mixed rotation includes both grain and N-fixing perennial legumes: canola-wheat-barley-brome/alfalfa mix- brome/alfalfa mix- brome/alfalfa mix.

To assess the soil biota, soil cores (4 cm in diameter at 15 cm depth) were collected from the test site in 1994 and 1995. Two to four cores were taken from each of the 216 sub-plots. Additional cores were taken from the perimeter of the test site, outside of the cropping area. For determination of soil arthropods, several techniques (Tullgren funnels, Baermann funnels) were used to extract the arthropods from the soil. The number and types of arthropods were determined. For the mycorrhizal fungi, a most-probable number (MPN) method was used to determine the number of living spores in each sample. Each soil sample was serially diluted with autoclaved sand, placed into Cone-tainers™ and seeded with alfalfa. After six weeks, roots were harvested, cleared and stained, root colonisation by mycorrhizal fungi assessed, and the number of mycorrhizal spores using MPN tables was determined.

THE FINDINGS

There is some variability at the site in the number, type and spatial distribution of arthropods and mycorrhizal spores in the soil. Acari (mites) are the most numerous arthropod group that were extracted from the soil using Tullgren funnels (Table 1). Within the Acari, Oribatids predominate the mite complex. In the insect group, Collembola make up more than 50% of the insect complex; the predominant family within Collembola is Isotomidae. The Baermann funnels are designed to extract organisms from the soil water. The results of the Baermann funnel extractions show that nematodes were most numerous followed by rotifers, enchytraeids and protozoa (Table 2).

Within the main plot, mycorrhizal spore densities ranged from 0 to 500 spores per 100 g of soil with the majority of soil samples containing 110 to 210 spores per 100g soil (Table 3). Soil cores taken from the outside of the cropping area on the west side of the site contained lower spore densities than the east side. However, these spore densities are similar to those reported in Saskatchewan and Alberta fields and they will differ according to cropping history.

Table 1. Summary of arthropods extracted from soil cores using Tullgren funnels.

Arthropod Group	Total Number	Diversity	% of Total
Insecta	336	Collembola	52
		Diptera	37
		Coleoptera	7
		Others	4
Collembola	174	Isotomidae	47
		Hypogasturidae	42
		Sminthuridae	11
Acari	1011	Oribatida	48
		Gamasida	22
		Actinedida	19
		Acarida	11

DISCUSSION

Soil microfauna are involved in a number of soil processes such as decomposition of organic matter, nutrient mineralization, regulating micro flora (including plant pathogens) and decomposition of agricultural chemicals (Gupta and Yeats 1997). Soil arthropods, especially those found in the soil water, can play a significant role in soil micro-biotic processes. Microarthropods are abundant in agricultural soils but are often not studied (Crossley *et al.* 1992). They are sensitive to agricultural chemical inputs and have potential as biological indicators of sustainability (Koehler 1992). Vesicular-arbuscular mycorrhizal fungi (VAM) are the most common of all soil fungi that form beneficial associations with approximately 90-95% of all vascular plants (Hayman 1981). Agricultural practices can have a very significant impact on VAM populations. Relatively little is known about the occurrence and importance of these fungi in intensive agriculture, although several investigations have been initiated (Baltruschat and Dehne, 1988; Stöppler et al., 1990; Vivekanandan and Fixen, 1991; McGonigle and Miller, 1993). Tillage and soil disturbance appear to reduce mycorrhizal colonization and significant reductions in level of mycorrhizal root colonization in crops after fallow has been reported (Kucey and Paul, 1983).

Table 2. Summary of microfauna extracted from soil cores using Baermann funnels.

MICROFAUNA	NUMBERS
Nematoda	14,638
Rotifera	743
Annelida (Enchytraeids)	542
Protozoa	104

As part of site characterization, the type and spatial distribution of soil arthropods and vesicular-arbuscular mycorrhizal fungi were determined during the first year of establishment of the field site. Site characterization provides a base-line value of major biological components that are being monitored over time. This allows the participants to assess the direction and rate of change that is occurring in these components as a function of the different cropping systems (treatments).

These studies are intended to serve as a guide for the development of sustainable cropping systems that provide a stable food supply, do not increase inputs of nonrenewable resources and preserve soil and environmental quality while maintaining or improving cropping potential.

ACKNOWLEDGMENTS

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Table 3. Number of viable VAM spores recovered from 520 soil cores based on *Most Probable Number* method.

Number of VAM Spores (per 100g of soil)	Field Plot Soil Cores (Frequency)	Field Margin Soil Cores (Frequency)
0	6	0
1 to 100	44	16
101 to 150	141	9
151 to 200	56	18
201 to 250	71	9
251 to 300	88	12
301 to 500	25	24
> 500	1	0
TOTAL	**432**	**88**

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ACKNOWLEDGING THE CONNECTIONS: WORLDVIEWS AND CONSERVATION

Lynn W. Oliphant

Department of Veterinary Anatomy, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5B4

Abstract: The many programs, proposed or in place, to preserve the endangered species and spaces of the planet are imbedded within a culture that promotes their destruction. Conservation efforts will inevitably fail or at best be severely limited by a need for a constant infusion of funds and personal energy by a handful of committed individuals, unless the current cultural paradigm is radically changed. Daniel Quinn defines the modern industrial worldview as the "Taker" culture versus the "Leaver" cultures typical of pre-agricultural humans. The Taker view is of a world "made for man, and man was made to conquer and rule it." The Leaver view is that the world "is a sacred place and we are a part of it." We must ask ourselves whether conservation programs that do not challenge the dominant worldview can possibly succeed, and if not, how can we promote the movement towards an ecological worldview. The shift to a new worldview based on ecological reality has the potential to achieve the goals of the conservation movement without conscious effort because they are automatically embedded within the culture.

Mainstream conservation programs to protect biodiversity and the ecological processes that sustain life on the planet rarely challenge the dominant paradigm of the "civilized" world. They are instead embedded in this worldview and are designed to tinker with the system to achieve rather limited short-term goals. The public is lulled into a complacency, "knowing" that biologists and other scientists are finding the answers to the myriad of environmental problems one by one, lulled into a false sense that everything will turn out all right without any real impact on their chosen lifestyle.

In reality, nothing could be farther from the truth. The industrial worldview sees wealth as being generated through unlimited economic growth; sees wealth as a product of human activity as we convert "natural capital" into human capital. This worldview, driven to a large extent by an economic system that is designed without reference to how the real world operates, is INCOMPATIBLE WITH THE GOALS OF THE WORLD CONSERVATION STRATEGY, namely to protect ecological processes and biodiversity at all levels. For many people, the whole notion of alternative worldviews is a novel concept. We do not tend to think about the basic assumptions that underlie our everyday activities. Yet it is these very assumptions that drive the direction of today's society in an unsustainable direction.

There have been many attempts to develop an ecocentric philosophy in contrast to the dominant anthropocentric viewpoint that puts man at the centre of all things (see Fox [1995] for a recent review). The current thrust is in the area known as Deep Ecology, but there have been many other earlier philosophical statements that put the needs of the ecosphere above those of humankind. One of the simplest and clearest is the Land Ethic of Aldo Leopold (1949): "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."

Many of the attempts at developing a coherent ecocentric approach (Naess 1989, Goldsmith 1996) are difficult to grasp without an intensive study of ecophilosophy that few people in society are liable to attempt. In contrast to these deep philosophical approaches, Daniel Quinn has written a series of novels (see Quinn 1997) that are easy to follow and exciting to read and that clearly explain the two contrasting worldviews. Quinn makes a very strong case that *programs* that require time, money and great human effort to carry out are really symptoms of a failure in the basic assumptions or worldview of society. They are like little sticks in a river that result in a few ripples but do nothing to change the overall course of the river.

If we wish to change the course of the river, much of the effort now put into keeping our little sticks in place must be shifted to a challenge of the basic institutions that determine the direction of society. Perhaps the most important area that is driving us towards an unsustainable future and the dramatic decline in biodiversity that we are currently experiencing is our economic system. It doesn't take a rocket scientist to realize that unlimited growth of the human economy can only be achieved at the expense of the economies of all other species. Without a change in the way we see our economic system and a decision that it needs to be radically redesigned, ALL CURRENT CONSERVATION EFFORTS WILL ULTIMATELY FAIL.

Unfortunately, a simple shift to an ecocentric world-view will not instantaneously make everything OK. I agree with Henry Epp (1997) that much more will be needed to ensure that the vision translates into action, but in the absence of such a vision we will continue to spin our wheels. We will be the sad witnesses to the rapid conversion of the world's stock of ecological capital (biodiversity) into paper dollars making a few individuals very rich for a very short time at the expense of all living things for an eternity. WHEN DO WE START?

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DIVERSITY OF AQUATIC MACROINVERTEBRATES IN SASKATCHEWAN

D.W. Parker

AquaTax Consulting, 1204 Main Street, Saskatoon, Saskatchewan S7H 0L2

D.M. Lehmkuhl

Department of Biology, 112 Science Place, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5E2

Abstract: The published literature and unpublished research data were used to determine the diversity and assess the systematic knowledge of aquatic macroinvertebrates in Saskatchewan. At least 1543 species of macroinvertebrates are reported from the province or are found in bordering areas. Species lists and provincial distributions are incomplete or do not exist for all but a few macroinvertebrate groups. Lack of this information is hampering ecological research, environmental impact assessments and the determination of habitats and species at risk in Saskatchewan. More basic systematic research must be done to fill the large gaps in our knowledge of the province's macroinvertebrate fauna.

INTRODUCTION

Macroinvertebrates inhabiting the rivers, streams, lakes and ponds of Saskatchewan play an integral role in the functioning of these ecosystems. They can be found at all trophic levels from primary consumers to top predators (Rosenberg and Resh 1993). They are an important part of aquatic food chains that support fish, water fowl, and other animals. Macroinvertebrates are also important tools for assessing the impact of developments on aquatic ecosystems (Rosenberg and Resh 1993). However, aquatic macroinvertebrates have not been extensively studied in Saskatchewan compared to other faunal groups. The resulting lack of knowledge is hampering ecological research and the assessment of development impacts on the aquatic environment and the province's biodiversity.

OBJECTIVES

The objectives of this research are to provide a preliminary overview of the aquatic macroinvertebrate fauna of Saskatchewan and assess the systematic information for the groups in the province. Ultimately, the objective will be to prepare improved species lists, distributions and taxonomic keys for the macroinvertebrates of the province.

METHODS

Published literature, unpublished research data and collection material were used to prepare a preliminary inventory and determine the state of systematic knowledge of aquatic macroinvertebrates in Saskatchewan.

RESULTS

The aquatic macroinvertebrate fauna of Saskatchewan is very diverse compared to other faunal groups (Figure 1). But little is known of the species diversity in the province. Government guidelines for environmental impact assessments require only family or generic level identifications for most macroinvertebrates (Environment Canada 1993). Similarly, most ecological research examines macroinvertebrate communities at supraspecific levels. Such studies do not recognize the potentially large difference between diversity at the family level and at the species level (Figure 2). These studies therefore do not appreciate the different environmental requirements and responses that different species within the same taxa may have (Resh and Unzicker 1975). This hampers the interpretation of ecological and impact assessment results. Such supraspecific research also squanders an opportunity to contribute to our knowledge of the biodiversity of these groups.

The following sections examine our knowledge of the diversity of aquatic insects and macroinvertebrates in Saskatchewan. A bias toward the aquatic insects is admitted as examination of the other groups is in a very preliminary stage.

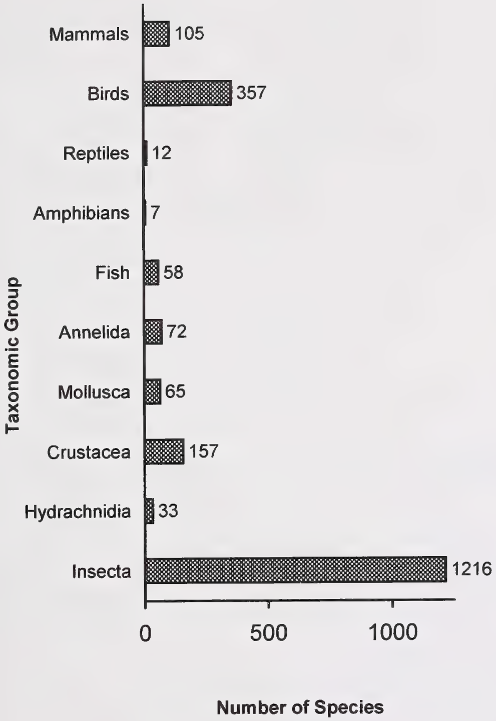

Figure 1. Diversity of aquatic macroinvertebrates and vertebrates in Saskatchewan

Annelida

To date 47 species of aquatic oligochaetes and 25 species of leeches have been recorded or are likely to occur in Saskatchewan (Brinkhurst 1976, Brinkhurst 1978, Clifford 1991, Davies 1971, Davies 1973). Most of this information must be extrapolated from larger scope studies since detailed species lists and distributions do not exist for the province.

Mollusca

Sixty-five species were reported from Saskatchewan by Clarke (1981) in his survey of Canada's molluscs. However, little detailed work has been done on this group within the province.

Crustacea

At least 157 species of Crustacea are likely to occur in Saskatchewan (Clifford 1991). While some of the groups are monotypic in Saskatchewan the copepods and cladocerans are more diverse with over 54 species each. A thorough study of the crustaceans has not been done for the province.

Arachnida

Very little work has been done on the aquatic mites of the province. The 33 species reported by Smith (1987) as inhabiting peatlands and marshes in Saskatchewan are likely only a small portion of the fauna present.

Insects

Eleven orders of aquatic insects are found in Saskatchewan (Figure 2). Our knowledge for most orders in the province is limited to a few isolated studies, or from broad scope surveys and taxonomic revisions which rely on incomplete data. Relatively complete provincial species lists and distributions are available for only a few groups. For most aquatic insect groups we are still unaware of the total number of species present in the province.

Twelve families and 83 species of Ephemeroptera are known from Saskatchewan (Lehmkuhl 1976, Whiting 1985). Relatively little has been published focusing on Saskatchewan mayflies other than a few ecological studies and systematic treatments of particular species.

The Saskatchewan odonate fauna includes at least 50 species belonging to seven families (Hilton 1987, Lehmkuhl 1975, Walker 1955, 1958, Walker and Corbet 1975, Westfall and May 1996). Although they are easily recognized by the public, information for the province is limited to incomplete distributions provided in Canadawide surveys and habitat specific ecological studies.

The stoneflies (Plecoptera) of Saskatchewan are relatively well known. Forty-seven species are recorded from the province. Dosdall and Lehmkuhl (1979, 1987) and Dosdall (1992) provide species information for most of the province.

A comprehensive taxonomic work of the aquatic Heteroptera of Saskatchewan is available in Brooks and Kelton (1967). Additional species records are presented by Scudder (1987). This order is quite diverse with 85 species reported from the province. Detailed distributional and ecological information for Saskatchewan is generally lacking.

Two minor orders, the Megaloptera and Neuroptera, appear to have only one species each in Saskatchewan; *Sialis velata* Ross, (Lehmkuhl 1975) and *Sisyra vicaria* (Walker) respectively.

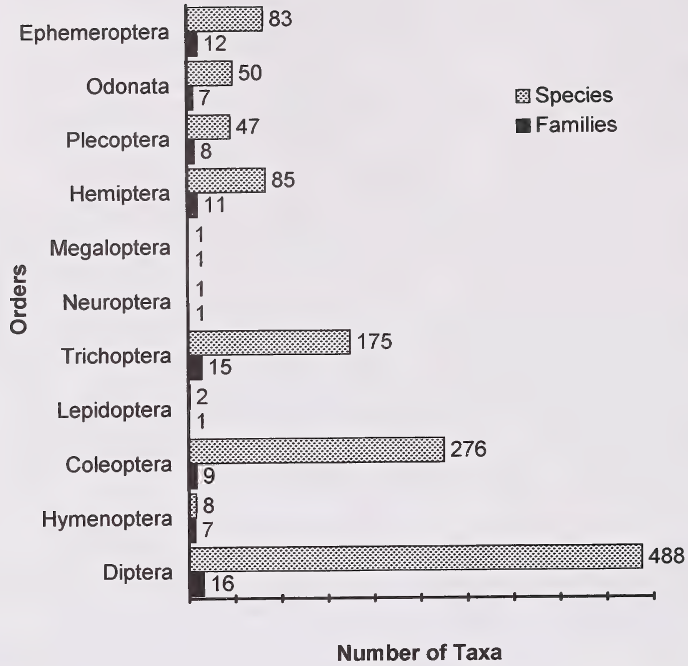

Figure 2. Biodiversity of the aquatic insects known from Saskatchewan at the species and family levels.

The biosystematics of Saskatchewan's caddisflies (Trichoptera) for the Saskatchewan River and boreal streams has been studied by Smith (1975, 1984). One hundred and seventy-five species have been recorded from Saskatchewan in Smith's works and other studies (Flannigan and Macdonald 1987, Nimmo 1971, Nimmo 1986, Nimmo 1987).

Another minor aquatic order is the Lepidoptera . This group has been very poorly studied in the province.

The aquatic beetles (Coleoptera) are very diverse with over 276 species reported from Saskatchewan. Most of the information available for the province's fauna must be extrapolated from research done in adjoining areas (i.e. Larson 1975) or from more broad surveys or taxonomic revisions (Larson 1987, Smetana 1988).

Due to their parasitic life history and difficult taxonomy the aquatic parasitic wasps (Hymenoptera) are usually overlooked. Undoubtedly there are numerous species to be found in Saskatchewan but only eight have so far been associated with their aquatic hosts from Saskatchewan material (Parker 1992).

The Diptera, true flies, is a large order with16 families and at least 488 species reported from the province. The state of our knowledge for most families in Saskatchewan is poor. However, some families such as the Culicidae (Rempel 1953) and Simuliidae (Fredeen 1985) have been relatively well studied in the province. The most diverse aquatic insect group is the dipteran family Chironomidae. This family is represented in the province by over 190 species (Mason et al. 1991, Mason and Parker 1994) even though the group has only been studied in detail in parts of the Saskatchewan River and a few lakes and ponds.

RARE SPECIES

At present there is no list of endangered aquatic macroinvertebrates for Saskatchewan. Too little information is available for most groups to determine if any species are at risk. However, there are a number of rare mayflies found in the Saskatchewan River system (Table 1) (Lehmkuhl 1970, Lehmkuhl 1972). These species were known from other large rivers in North America but these rivers have been altered by reservoirs and pollutants to such an extent the species likely no longer exist in them (Lehmkuhl 1970). Dams already on

Table 1. Rare and potentially threatened Mayflies of the Saskatchewan River system.

Ametropus albrighti	Traver
Dactylobaetis sp.	
Acanthomola pubescens	Whiting and Lehmkuhl
Anepeorus rusticus	McDunnough
Pseudiron centralis	McDunnough
Raptoheptagenia cruentata	(Walsh)
Macdunnoa nipawinia	Lehmkuhl
Choroterpes albiannulata	McDunnough
Traverella albertana	(McDunnough)
Lachlania saskatchewanensis	Ide
Analetris exima	Edmunds
Trichorythodes corpulentus	Kilgore & Allen

the Saskatchewan Rivers have drastically altered the downstream ecosystems and aquatic insect communities (Lehmkuhl 1972, Mason and Lehmkuhl 1983). Any further alterations to the Saskatchewan River system will likely eliminate this unique mayfly community from the system and possibly cause the complete extinction of a number of species.

CONCLUSIONS AND FUTURE RESEARCH

This preliminary research has shown that the species diversity of aquatic insects and other aquatic macroinvertebrates in Saskatchewan is large. However, the task of documenting the species diversity for the province is incomplete. Systematic studies by competent researchers must be undertaken to evaluate the biodiversity of macroinvertebrates and determine species that may be at risk of extinction. Until such work is completed we will not have a full appreciation of the diversity of these groups in the province nor will we be able to develop environmentally sound management practices to protect our aquatic environment and biodiversity for the future.

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RESPONSES OF SMALL MAMMALS TO LAND FRAGMENTATION AND HABITAT EDGES

Maria Pasitschniak-Arts and François Messier
Department of Biology, University of Saskatchewan, 112 Science Place, Saskatoon, Saskatchewan S7N 5E2

Abstract: From 1991-1993, we investigated the abundance and distribution of small mammals relative to edge in the fragmented landscape of the Canadian prairies. Small mammals were snap-trapped (Museum Specials) in four different habitat types: idle pasture, delayed hay, dense nesting cover, and rights-of-way. Artificial duck nests (n = 1350) were set up at the same time and in the same replicates where small mammals were being monitored. All nests were checked weekly, and a successful nest was defined as one where 1 egg survived for 28 d. A total of 995 small mammals, representing nine species, were captured. No edge effect was recorded in idle pasture or dense nesting cover; however, an edge effect was observed in delayed hay fields. Of the two most common species captured, *Peromyscus maniculatus* showed no affinity for edges, while *Microtus pennsylvanicus* was significantly more abundant along edges compared to the habitat interior. Relative abundance of small mammals was highest in dense nesting cover, intermediate in delayed hay and along rights-of-way, and lowest in idle pasture. Since small mammals are an important prey source to several species of generalist duck nest predators, we postulated that habitats with a greater abundance of small mammals would buffer duck nests, resulting in higher duck nesting success. We observed a positive correlation between relative abundance of small mammals and survival rate of artificial duck nests.

EFFECTS OF FARMING PRACTICES IN SASKATCHEWAN ON ARTHROPOD ABUNDANCE AND SPECIES DIVERSITY

Ken Pivnick

Prairie Earth, Box 306, Blaine Lake, Saskatchewan S0J 0J0

Abstract: As part of a larger study of the effect of farming practices on biodiversity carried out by the Saskatchewan Research Council, I investigated the abundance and species diversity of butterflies, ground beetles, and spiders at four paired sites in different soil zones of the province: 1) Black soil zone near St. Denis: a) most of the aspen bluffs removed and cultivated vs b) aspen bluffs intact; 2) Dark brown soil zone near Hanley: a) cultivated field vs b) cultivated field with shelterbelts; 3) Brown soil zone near Hodgeville: a) organic vs b) conventional farms; and 4) Black soil zone near North Battleford: a) fescue prairie vs b) planted forage pasture. In 1, 2, and 3, subsites of remnant native prairie were compared to the rest of the site. Insect surveys were carried out in six to eight visits per summer over two summers. Butterflies were censused by planned walk-throughs with identification on the wing and with net captures. Beetles and spiders were censused by pit traps.

For butterflies, the highest number of species (species richness) was found in native prairie. The largest tract of native prairie (at Hatherleigh) had more species than the small prairie remnants. For ground beetles, cultivated fields, treed areas, shelterbelts, and an intermittently cultivated wetland area had higher species richness and absolute numbers than native prairie, which did not differ from tame pasture. The low numbers of beetles caught in native prairie may reflect higher prey density here given the habits of these insects and the pit traps used. The Simpson's species diversity index for ground beetles was generally lowest in cultivated fields, indicating that these fields were dominated by a few species. Habitat diversity was important for some ground beetles which required the presence of wooded areas or wetlands. Spider species richness was highest in treed areas and in the large tract of native prairie at Hatherleigh. Richness was low in smaller tracts of native prairie and in cultivated fields; the latter also had low spider abundance. The organic farm showed no differences from the conventional farm. The results suggest that the conservation of native prairie areas and wooded areas will encourage high butterfly, spider, and at least to a lesser extent, ground beetle diversity. The larger the area, the greater is the species richness.

INTRODUCTION

Agricultural activities tend to impoverish the species diversity, species richness and vitality of biological communities, especially where till agriculture is concerned. Agricultural activities are the primary land uses of the mixed grass prairie and aspen parkland which make up the southern portion of the prairie provinces. The land has been modified for these purposes to the extent that only 20-25% of this area can even nominally be considered to be mixed grass prairie or aspen parkland (World Wildlife Fund Canada 1987). Clearly, though, because of the overwhelming impact of agriculture on the landscape, many subtle changes in agricultural practices may have serious implications for the land, for better or for worse. In this study, as part of a larger study undertaken by the Saskatchewan Research Council of the effects of farming practices on biodiversity, I have examined species diversity and richness of butterflies, ground beetles, and spiders as a function of some agricultural land use practices. As a group the arthropods are the most diverse group of organisms on the planet and are greatly undervalued, poorly understood, and of inestimable importance to the health of the land.

METHODS

Sampling was carried out at four sites over three years (two years for each site). At each site, paired fields were sampled for comparison. In most cases, two distinct plant communities were sampled within each field.

Sampling Dates

Sampling was carried out from May to August. Sites at St. Denis, Hanley and Hodgeville were sampled 7 times in 1995 (May 4-August 21) and 6 times in 1996 (June 2-August 28; sampling was started late in 1996 because of a cool, wet spring). Sites at the Hatherleigh Provincial Community Pasture were also sampled six times in 1996 (June 6-August 26) and 8 times in 1997 (May 6-August 26). In 1995, pit trap sampling was started (on the second visit) at some sites because farmers had not finished spring seeding. This incomplete early data is not presented to allow appropriate comparisons because the data is summed over the season. Where appropriate for the sake of simplicity, the 1997 data for Hatherleigh is presented with the 1995 data for the other sites.

Sample Sites

Where designated a and b, this indicates that these were treated as two distinct sites for pit traps but not for the butterfly survey. At the planted pasture at Hatherleigh, the field was divided into an east and west half as an internal comparison to examine the consistency of trapping results. Sites were as follows.

St. Denis: 4 sites at Procyshyn farm: 1a. native grassland, 1b. treed areas within grassland, 2a. cultivated field (lentils '95; Durham wheat '96), 2b. treed areas within a cultivated field; 2 sites at Deptuck farm: 3a. cultivated field (fallow, canola '95; canola, flax '96), 3b. cultivated wetlands (as moisture levels allow).

Hanley: 4 sites at Hanson farm: 1. native grassland, 2. cultivated field (barley, wheat '95; field peas, canola '96), 3a. cultivated field (fallow, wheat '95; wheat, fallow '96), 3b. shelterbelts (Siberian elm, carragana) within the cultivated field.

Hodgeville: 2 sites at Rempel organic farm: 1. cultivated field (wheat, clover, field peas, barley), 2. abandoned rail right-of-way running through the cultivated field; 2 sites at Watson conventional farm: 3. cultivated field (wheat), 4. abandoned rail right-of-way running through the cultivated field.

Hatherleigh: 4 sites at the Provincial Community Pasture: 1a. native fescue prairie - open grassland, 1b. treed areas within grassland, 2a. planted pasture (alfalfa and grasses) - east half, 2b. planted pasture - west end (as an internal comparison of sampling variability).

Sampling Methods

Pit Traps: These traps were installed to collect ground beetles (family Carabidae, Order Coleoptera) and spiders (order Areneida). A few butterflies were also collected. Insects collected are reported together by category and not by sampling method. For the pit traps, 450 ml plastic beer glasses were dug into the ground so that the top was level with the ground surface. These were covered by 24 cm square particle board raised 2 cm on each corner. The traps were half filled with a 1:1 mixture of ethylene glycol and water. Solutions were replenished or replaced as needed. The one exception to this solution was the cultivated field traps at Hodgeville in 1995 only which contained a saturated table salt-water solution with 10 ml of dish detergent per litre, used to accommodate the request of the farmer at this site. This solution did not preserve specimens adequately, and incomplete results were obtained (not included). Ethylene glycol was used here in 1996.

Twelve traps were installed at each site. The collected insects, however, were pooled as they were collected. Insect samples were preserved in the ethylene glycol solution until sorted and pinned. Numbers and species were recorded. On unusually large samples, sub-samples only were sorted. Major losses of pit traps and their contents due to cattle activity occurred at Hatherleigh (18 and 28% of traps in native fescue and tame pasture respectively, removed over the season in 1996; 17 and 7% in 1997). Ground beetles were identified according to Lindroth (1961-69) except for *Harpalus solitaris* (=*H. fuliginosus* of Lindroth [1961-69]).

Butterfly Survey: On each visit, butterflies were surveyed while attending pit traps. Where possible, visits were planned to take advantage of warm, sunny, calm weather as these conditions facilitated butterfly activity. Because of the mobile nature of the butterflies, sampling was combined for two habitat types within a given field (where applicable). Therefore, each combined sample site was sampled on each date for 1-4 hours. Butterflies were caught as needed for identification. Where possible, they were identified on the wing. Butterfly names follow Hall et al. (1998).

Net Sweeps: Four times 50 net sweeps using a 38-cm diameter insect sweep net were taken at four locations within each site on each sampling date. The samples from a given site were bagged and pooled, placed in a cooler until they could be frozen and then sorted and identified. This method was discontinued after 1995.

Sample Analysis

Identifications of butterflies and beetles were confirmed by Ron Hooper at the Natural History Museum in Regina or by comparison with the Museum collection. The spiders were all identified by Donald J. Buckle of Saskatoon, who has the largest personal collection of spiders in Saskatchewan. The main spider references used for identification were Aitchison-Benell and Dondale 1990; Kaston 1948; and Roth 1993. Simpson's Index of Diversity D, a measure of the evenness of species abundance (Krebs 1978), was calculated for spider and beetle samples.

RESULTS AND DISCUSSION

Butterflies

Forty-three of the ca. 160 spp. found in Saskatchewan were found in this survey (Tables 1a, b, and c). Native grassland areas contained more species and usually more individuals than did cultivated fields (St. Denis, Hanley) or planted pastures (Hatherleigh) within the same locality. Where the sizes of the fields were large and comparable in size (Hatherleigh), native prairie yielded almost three times the number of species. Elsewhere, the native prairie was small (ca. 10 ha) and much smaller than the compared fields. Here the native prairie contained more species, but the differences were smaller. Cultivated fields also contained more species if they contained wooded area (St. Denis) but the presence of shelterbelts (carragana and Siberian elm) within a cultivated field had no effect (Hanley). The rail right-of-way, composed of perennial weedy species and native grasses, also supported substantially more butterfly species than the adjacent cultivated fields. There was no difference between the conventional and organic fields at Hodgeville. The only time one might expect an important difference would be in the case of high insecticidal use, which did not occur on the study farms. Total butterfly numbers have to be interpreted carefully as certain highly mobile, very common species tend to be most abundant where the plant diversity is the least. Cabbage whites, *Pieris rapae* L., often achieve very high densities in canola fields (the larval host plants are crucifers) as do clouded sulphurs, *Colias philodice* Godart, in alfalfa fields (the larvae feed on legumes).

The differences in butterfly species richness between cultivated fields and native prairie are to be expected. Of approximately 140 resident species found in the prairie region of Saskatchewan, 49 species are found primarily in native prairie, 45 in woodlands, 18 in wetlands, and only about 17 primarily in weedy or disturbed environments. These latter 17 species use primarily weedy species upon which to lay their eggs and which their larvae eat. However, one can expect far fewer species than this in grain fields as there are usually few flowers there from which the butterflies can obtain nectar, which is their other principal requirement.

Most butterfly species are quite sedentary, do not like to cross habitat boundaries and, therefore tend to be found where their larval food plant occurs. This tendency enhances the persistence of small populations in remnant habitats. For instance, the Milbert's tortoiseshell, *Nymphalis milberti* (Godart), was found in the rail right-of-way where its larval food plant (stinging nettles, *Urtica dioica* L.) was found in profusion but not in the adjacent cultivated fields. The two species of arctics (*Oeneis* spp.) were found in the native prairie at Hatherleigh where their larval host plants (fescue and needle grasses *Festuca* and *Stipa* spp.) are found but not in the planted pasture. Hence, as plant diversity increases, so does butterfly richness. The low plant species richness in both organic and conventional cultivated fields at Hodgeville and the overwhelming influence of till agriculture in this area with its negative effect on butterfly diversity were far more important than any differences between organic and conventional fields.

Topographic diversity also has its influences. The moist edge of the dugout in the native pasture at Hatherleigh was the site of large aggregations of butterflies seeking moisture and minerals on hot days. Also, the abundant hilltops in the same field were well frequented by several of the fritillary species as these tend to be mating sites.

In summary, butterfly abundance and diversity was higher in native prairie, even small patches of ca. 10 ha, than in cultivated fields. The presence of treed areas or abandoned weedy patches also increased diversity but single or two species shelterbelts did not.

Ground Beetles

In this survey, 91 species of ground beetles have been sampled of the 322 ground beetle species (including 18 tiger beetle spp.) know in Saskatchewan (see Tables 2a and b). This includes one new record for the prairie provinces, *Harpalus somnulentus* Dejean, collected at Hodgeville. Beetle species richness and absolute abundance were higher in cultivated fields, treed areas, shelterbelts and the intermittently cultivated wetland, than in native prairie which, at Hatherleigh, did not differ from the tame pasture. The large native prairie at Hatherleigh did not turn up more species than the small prairie remnants. On the other hand, species evenness (D) was generally lowest in cultivated fields and highest in treed areas and shelterbelts, indicating high numbers of relatively few species in cultivated areas,

Table 1a. Numbers of butterflies in 1995 and 1997. See Table 1c for latin names and abbreviations key.

SPECIES	ST D 1995			HAN 1995			HODGE 1995				HATH 1997	
	Na	CA	Cu	Na	Cu	CS	Or-R	Or-C	Co-R	Co-C	Na	Ta
PIERIDAE												
Cabbage White	81	217	170	43	308	81	14	3	8	2	8	45
Western White	3	2	17	9	29	4	9	2	5	0	2	34
Clouded Sulphur	16	2	0	20	5	11	2	0	2	0	35	98
Christina Sulphur	0	0	0	0	0	0	0	0	0	0	8	0
Olympia Marble	0	0	0	0	0	0	0	0	0	0	0	0
NYMPHALIDAE												
Common Ringlet	51	2	2	39	4	0	6	0	7	0	21	7
Common Alpine	3	1	0	0	0	0	0	0	0	0	2	0
Red-disked Alpine	0	0	0	0	0	0	0	0	0	0	1	0
Com. Wood Nymph	168	14	0	82	1	5	9	0	9	0	49	23
Alberta Arctic	0	0	0	0	0	0	0	0	0	0	1	0
Uhler's Arctic	0	0	0	0	0	0	0	0	0	0	2	0
Milbert's TS	8	5	1	0	4	0	20	0	7	0	0	0
Mourning Cloak	3	0	0	0	0	0	1	0	0	0	2	0
Grey Comma	8	11	0	0	0	0	0	0	0	0	0	0
Painted Lady	15	8	16	12	34	13	10	3	15	3	0	0
White Admiral	19	20	0	0	0	0	0	0	0	0	0	0
Viceroy	1	1	0	0	0	0	0	0	0	0	0	0
Meadow F	6	1	1	0	0	0	0	0	0	0	1	0
Gt. Spangled F	66	30	0	6	0	0	3	0	6	0	2	0
Northwestern F	23	1	0	17	0	0	0	0	0	0	0	2
Aphrodite F	4	0	0	4	0	0	0	0	0	0	3	0
Mormon F	0	0	0	0	0	0	0	0	0	0	15	9
Callippe F	0	0	0	0	0	0	0	0	0	0	4	0
Variegated F	0	0	0	1	0	0	1	0	0	0	1	0
Northern CR	9	19	1	1	0	0	0	0	0	0	3	0
Tawny CR	0	0	0	0	0	0	0	0	0	0	3	0
LYCAENIDAE												
Greenish Blue	48	5	0	7	1	4	0	0	0	0	0	0
Silvery Blue	17	0	0	0	0	1	0	0	0	0	3	0
Melissa Blue	0	0	0	1	0	0	0	0	0	0	0	0
Northern Blue	0	0	0	0	0	0	0	0	0	0	0	0
Spring Azue	0	0	0	0	0	0	0	0	0	0	0	0
Purplish Copper	0	2	2	2	0	0	0	0	0	0	0	0
Bronze Copper	0	0	0	1	0	0	0	0	0	0	0	0
Brown Elfin	0	0	0	0	0	0	0	0	0	0	0	0
PAPILIONIDAE												
Can. Tiger SWT	0	1	0	0	0	0	0	0	0	0	0	0
HESPERIIDAE												
Persius DW	8	0	0	0	0	0	0	0	0	0	0	0
Dreamy DW	0	0	0	0	0	0	0	0	0	0	0	0
Garita Skipperling	97	0	0	3	0	0	2	0	2	0	3	0
Long Dash SK	1	1	0	0	0	0	0	0	0	0	0	0
Peck's SK	0	0	0	0	0	0	0	0	0	0	0	0
Tawny-edged SK	0	0	0	0	0	0	0	0	0	0	1	0
Nevada SK	0	0	2	0	0	0	0	0	0	0	0	0
Plains SK	0	0	0	0	0	0	0	0	0	0	1	0
TOTAL SPECIES	22	19	9	16	8	7	11	3	9	2	23	7
TOTAL NUMBERS	655	343	212	248	386	120	77	8	61	5	171	218

Table 1b. Number of butterflies in 1996. See Table 1c for latin names and abbreviations key.

SPECIES	ST D 1996			HAN 1996			HODGE 1996				HATH 1996	
	Na	CA	Cu	Na	Cu	CS	Or-R	Or-C	Co-R	Co-C	Na	Ta
PIERIDAE												
Cabbage White	15	12	25	17	22	21	18	5	10	2	2	2
Western White	0	0	1	6	1	0	2	1	1	0	1	2
Clouded Sulphur	37	2	6	140	3	9	21	11	12	5	33	11
Christina Sulphur	0	0	0	1	0	0	0	0	0	0	2	0
Olympia Marble	0	0	0	0	0	0	0	0	0	0	3	0
NYMPHALIDAE												
Common Ringlet	13	1	0	4	0	0	7	0	19	1	41	3
Common Alpine	12	0	0	0	0	0	0	0	0	0	1	0
Red-disked Alpine	0	0	0	0	0	0	0	0	0	0	0	0
Com. Wood Nymph	170	5	1	73	1	2	10	0	6	0	78	4
Alberta Arctic	0	0	0	0	0	0	0	0	0	0	4	0
Uhler's Arctic	0	0	0	0	0	0	0	0	0	0	0	0
Milbert's TS	0	0	0	0	0	0	3	0	3	0	0	0
Mourning Cloak	0	0	0	0	0	2	0	0	0	0	0	0
Grey Comma	0	0	0	0	0	0	0	0	0	0	0	0
Painted Lady	0	0	0	0	0	0	0	0	0	0	0	0
White Admiral	6	6	0	0	0	0	1	0	2	0	0	0
Viceroy	0	0	0	0	0	0	0	0	0	0	0	0
Meadow F	10	0	0	0	1	0	0	0	0	0	1	0
Gt. Spangled F	22	1	0	0	0	0	8	0	3	0	4	0
Northwestern F	0	0	0	0	0	0	0	0	0	0	16	0
Aphrodite F	1	0	0	6	0	0	0	0	0	0	0	0
Mormon F	0	0	0	0	0	0	0	0	0	0	32	1
Callippe F	0	0	0	0	0	0	0	0	0	0	7	0
Variegated F	0	0	0	0	0	0	0	0	0	0	0	0
Northern CR	19	6	1	1	0	0	1	0	0	0	15	1
Tawny CR	0	0	0	0	0	0	0	0	0	0	8	0
LYCAENIDAE												
Greenish Blue	5	0	0	1	1	0	0	0	0	0	0	1
Silvery Blue	1	0	0	0	0	0	0	0	0	0	4	2
Melissa Blue	1	0	0	4	0	0	0	0	4	0	0	0
Northern Blue	1	0	0	0	0	0	0	0	0	0	0	0
Spring Azue	1	0	0	0	0	0	0	0	0	0	0	0
Purplish Copper	0	0	0	0	0	0	0	0	0	0	0	0
Bronze Copper	0	0	0	0	0	0	0	0	0	0	0	0
Brown Elfin	0	0	0	0	0	0	0	0	0	0	1	0
PAPILIONIDAE												
Can. Tiger SWT	2	1	0	0	0	0	0	0	0	0	1	0
HESPERIIDAE												
Persius DW	0	0	0	0	0	0	0	0	0	0	16	0
Dreamy DW	0	0	0	0	0	0	0	0	0	0	4	0
Garita Skipperling	17	0	0	0	0	0	1	0	1	0	0	0
Long Dash SK	4	0	0	0	0	0	0	0	0	0	0	0
Peck's SK	0	0	0	0	0	0	0	0	2	0	0	0
Tawny-edged SK	0	0	0	0	0	0	0	0	0	0	0	0
Nevada SK	0	0	0	0	0	0	0	0	0	0	0	2
Plains SK	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL SPECIES	18	8	5	10	6	4	10	3	11	3	21	10
TOTAL NUMBERS	337	34	34	253	29	34	72	17	63	8	274	29
2-YR TOTAL SPP	26	19	11	16	9	7	13	4	13	4	29	10
2-YR TOTAL NO	992	377	246	501	411	154	149	25	124	13	445	246

Table 1c. Butterfly latin names and key to abbreviations in Tables 1a and 1b.

COMMON NAME	LATIN NAME	TAXONOMIC AUTHORITY	ABBREV.	MEANING
PIERIDAE			LOCATION	
Cabbage White	*Pieris rapae*	L.	ST D	St. Denis, SASK
Western White	*Pontia occidentalis*	(Reakirt)	HAN	Hanley, SASK
Clouded Sulphur	*Colias philodice*	Godart	HODGE	Hodgeville, SASK
Christina Sulphur	*C. christina*	Edwards	HATH	Hatherleigh Community
Olympia Marble	*Euchloe olympia*	(Edwards)		Pasture, SASK
NYMPHALIDAE			SITES	
Common Ringlet	*Coenonympha tullia*	(Müller)	Na	Native prairie
Common Alpine	*Erebia epipsodea*	Butler	CA	Cultivated field with
Red-disked Alpine	*E. discoidalis*	(Kirby)		Aspen bluffs
Common Wood Nymph	*Cercyonis pegala*	(F.)	Cu	Cultivated field
Alberta Arctic	*Oeneis alberta*	Elwes	CS	Cultivated field with
Uhler's Arctic	*O. uhleri*	(Reakirt)		Shelterbelts
Milbert's Tortoiseshell	*Nymphalis milberti*	(Godart)	Or-R	Organic cultivated field
Mourning Cloak	*N. antiopa*	(L.)		- abandoned Rail portion
Grey Comma	*Polygonia progne*	(Cramer)	Or-C	Organic cultivated field
Painted Lady	*Vanessa cardui*	(L.)		- Cultivated portion
White Admiral	*Limenitis arthemis*	(Drury)	Co-R	Conventional cult. field
Viceroy	*L. archippus*	(Cramer)		- abandoned Rail portion
Meadow Fritillary	*Boloria bellona*	(F.)	Co-C	Conventional cult. field
Great Spangled Fritillary	*Speyeria cybele*	(F.)		- Cultivated portion
Northwestern Fritillary	*S. hesperis*	(Edwards)	Ta	Tame grass field
Aphrodite Fritillary	*S. aphrodite*	(F.)		
Mormon Fritillary	*S. mormonia*	(Boisduval)		
Callippe Fritillary	*S. callippe*	(Boisduval)	COMMON	
Variegated Fritillary	*Euptoieta claudia*	(Cramer)	NAMES	
Northern Crescent	*Phyciodes cocyta*	(Cramer)		
Tawny Crescent	*P. batesii*	(Reakirt)	TS	Tortoiseshell
LYCAENIDAE			F	Fritillary
Greenish Blue	*Plebejus saepiolus*	(Boisduval)		
Silvery Blue	*Glaucopsyche lygdamus*	(Doubleday)	CR	Crescentspot
Melissa Blue	*Lycaeides melissa*	(Edwards)		
Northern Blue	*L. idas*	(L.)	SWT	Swallowtail
Spring Azure	*Celastrina ladon*	(Cramer)		
Purplish Copper	*Lycaena helloides*	(Boisduval)	DW	Duskywing
Bronze Copper	*L. hyllus*	(Cramer)		
Brown Elfin	*Callophrys augustinus*	(Westwood)	SK	Skipper
PAPILIONIDAE				
Canadian Tiger SWT	*Papilio canadensis*	Rothschild & Jordan		
HESPERIIDAE				
Persius Duskywing	*Erynnis persius*	(Scudder)		
Dreamy Duskywing	*E. icelus*	(Scudder & Burgess)		
Garita Skipperling	*Oarisma garita*	(Reakirt)		
Long Dash Skipper	*Polites mystic*	(Edwards)		
Peck's Skipper	*P. peckius*	(Kirby)		
Tawny-edged Skipper	*P. themistocles*	(Latreille)		
Nevada Skipper	*Hesperia nevada*	(Scudder)		
Plains Skipper	*H. assiniboia*	(Lyman)		

Table 2a. Ground beetles sampled 1995-97. See Table 2b for abbreviations key.

Sites	Total Numbers		Species Numbers		Diversity Index	
	1995/97*	1996	1995/97	1996	1995/97	1996
St Denis						
Na - O	140	152	14	11	0.76	0.68
Na-T	347	325	19	17	0.95	0.74
CA-O	161	1876	20	29	0.9	0.61
CA-T	396	837	21	29	0.8	0.67
Cu-O	406	468	17	31	0.67	0.8
Cu-W	310	477	27	27	0.84	0.74
Hanley						
Na-O	66	89	15	12	0.84	0.71
Cu-O	1288	3247	17	24	0.65	0.34
CS-O	469	1057	12	15	0.43	0.11
CS-S	313	136	24	24	0.88	0.9
Hodgeville						
Or-R	3096	764	28	24	0.84	0.88
Or-C		8110		25		0.82
Co-R	1363	504	31	29	0.79	0.88
Co-C		6351		23		0.7
Hatherleigh						
Na-O	104	129	4	13	0.44	0.72
Na-T	131	286	14	13	0.78	0.5
Ta-E	342	136	15	9	0.41	0.75
Ta-W	384	89	16	11	0.42	0.86

*1995/97 refers to 1997 data for Hatherleigh, 1995 for the other sites

and the most even species abundance in the most stable environments. The similar results in the east and west portions of the Hatherleigh tame grass pasture indicated a high level of repeatability of the pit trap captures.

Ground beetles, which range in size from 1-30 mm in length, are mostly generalist predators which run or burrow. Larval habits are similar. An exception occurs in the large *Harpalus* and *Amara* genera which are generally only carnivorous as larvae. Only the *Bembidion* and *Cicindela* genera are strong fliers. Because of these ground beetle characteristics, the effects of farming practices on abundance and species diversity could be expected to be somewhat different than on butterflies. However, Arnason (1941) found seven times higher arthropod populations in native prairie as opposed to wheat fields in a 10-year study near Saskatoon. This was thought to be primarily due to the early season absence of vegetation in the cultivated fields which limited insect use of the habitat during an important insect population growth phase. Assuming a similar situation in the present study, the low beetle numbers in native prairie as compared to cultivated fields may be an artefact of pit-trapping. With higher prey density in native prairie, beetles may move much less and therefore be caught less especially early in the season when the greatest total and species numbers were caught. Certainly the high species to individuals caught ratio in native prairie would also indicate that the trap catch is lower than expected. The species richness tended to be highest across all sites early in the season. This suggests that most of the species have a single generation and attain the adult stage in the spring, likely overwintering as late instar larvae, pupae or adults.

The shelter belt had no effect on the adjacent field although the samples from the shelterbelts themselves showed relatively high species richness and total abundance. The organic vs conventional cultivated field comparison again showed no difference in species richness. The abandoned rail line had quite high species richness and abundance but not as much as that of the

Table 2b. Ground beetle species collected and key to abbreviations in Tables 2a and 3.

LATIN NAMES	LATIN NAMES	ABBR.	MEANING
Chlaenius sericeus (Forst.)	*Patrobus lecontei* Chaudoir		
C. alternatus Horn	*Platynus decentis* (Say)	ST D	St. Denis, SASK
C. purpuricollis Randall	*Agonum placidum* (Say)		
C. nebraskensis LeConte	*A. cupreum* Dejean	HAN	Hanley, SASK
Carabus serratus Say	*A. corvus* (LeConte)		
C. taedatus LeC.	*A. cupripenne* (Say)	HODGE	Hodgeville, SASK
C. maeander Fischer	*A. sordens* (Kirby)		
Callisthenes luxatam Say	*A. gratiosum* (Manh.)	HATH	Hatherleigh Community
Calasoma frigidum Kirby	*A. retractum* (LeC.)		Pasture, SASK
C. lepidum LeC.	*A. thoreyi* Dejean		
C. obsoletum (Say)	*A. picicornoides* Lth.	Na-O	Native prairie
C. calidum (F.)	*A. errans* (Say)		-Open portion
Cicindela nebraskana Casey	*A. lutulentum* (LeConte)	Na-T	Native prairie
C. limbalis Klug	*Loricera pilicornis* (F.)		-Treed portion
C. purpurea LeC.	*Harpalus carbonatus* LeC.	CA-O	Cultiv. field with Aspen
Elaphrus clairvillei Kirby	*H. amputatus* (Say)		Bluffs - Open portion
P. adstrictus Eschscholtz	*H. pleuriticus* (Kirby)	CA-T	Cultiv. field with Aspen
P. femoralis Kirby	*H. uteanus* Casey		Bluffs - Treed portion
P. pennsylvanicus LeC.	*H. funerarius* Csiki	Cu-O	Cultivated field
Pterostichus patruelis Dej.	*H. solitarius* Dejean		- Open portion
Blethisa multipunctata FvW.	*H. opacipennis* (Hald.)	Cu-W	Cultivated field
Poecilus lucublandus (Say)	*H. fulvilabris* Mnh.		- cultiv. Wetland
P. corvus (LeConte)	*H. herbivagus* Say		
D. striatopunctata LeC.	*H. ventralis* LeConte	CS-O	Cultiv. field with Shelterbelts
Diplocheila oregona (Hatch)	*H. ellipsis* LeConte		- Open portion
Amara farcta (LeConte)	*H. lewisi* LeConte	CS-S	Cultiv. field with Shelterbelts
A. confusa (LeConte)	*H. egregius* Casey		- Shelterbelts
A. lunicollis Schiodte	*H. desertus* LeConte		
A. convexa (LeConte)	*H. somnulentus* Dejean	Or-R	Organic cultiv. field
A. littoralis Mann	*H. fallax* LeConte		-abandoned Rail portion
A. cupreolata (Putzeys)	*Harpalellus basilaris* (Kirby)	Or-C	Organic cultiv. field
A. obesa (Say)	*Stenopholus fuliginosus* Dej.		-Cultivated portion
A. latior (Latior)	*Anisodactylus nigrita* Dej.	Co-R	Conventional cult. field
A. quenseli (Schonherr.)	*A. harrisi* LeConte		-abandoned Rail portion
A. lacustris LeConte		Co-C	Conventional cult. field
A. carinata (LeConte)			-Cultivated portion
A. ellipsis Casey			
A. apricaria Paykull		Ta-E	Tame grass-east half
B. obscurellum (Mots.)		Ta-W	Tame grass-west half
Bembidion roosvelti Pic.			
B. quadrimaculatum L.			
B. nitidum (Kirby)		D	Simpson's Index
B. rupicola (Kirby)			of Diversity
B. acutifrons (LeConte)			
B. aeneicolle (LeConte)			
B. bimaculatum (Kirby)			
B. canadianum Casey			
B. muscicola Hayward			
B. praticola Lindroth			
Badister neopulchellus Lth.			
Syntomus americanus (Dej.)			
M. curtipennis (Casey)			
Microlestes linearis (LeC.)			
Cymindis cribricollis (Dej.)			
C. plannipennis (LeC.)			
Calathus ingratus Dej.			
Synuchus impunctatus (Say)			

Table 3. Spiders sampled 1995-97. See Table 2b for abbreviations key.

Sites	Total Numbers		Species Numbers		Diversity Index	
	1995/97*	1996	1995/97	1996	1995/97	1996
St Denis						
Na-O	201	274	22	34	0.8	0.81
Na-T	298	354	36	47	0.85	0.58
CA-O	39	72	15	32	0.82	0.94
CA-T	429	400	42	46	0.68	0.86
Cu-O	137	176	28	28	0.82	0.69
Cu-W	355	657	31	37	0.88	0.83
Hanley						
Na-O	322	378	29	28	0.78	0.73
Cu-O	532	116	36	34	0.83	0.94
CS-O	280	439	25	35	0.68	0.84
CS-S	556	319	36	33	0.51	0.82
Hodgeville						
Or-R	562	356	50	30	0.9	0.86
Or-C		244		26		0.83
Co-R	397	404	27	30	0.9	0.76
Co-C		396		25		0.8
Hatherleigh						
Na-O		406		41		0.8
Na-T		499		46		0.65
Ta-E		184		21		0.84
Ta-W		217		29		0.85

*1995/97 refers to 1997 data for Hatherleigh, 1995 for the other sites

cultivated field. While the rail line areas are more or less native prairie remnants, they are spread out in a narrow band within the cultivated field, causing their insect catch profiles to more closely resemble that of the cultivated fields than is the case for the other native prairie areas sampled.

While most species tended to appear across all habitats sampled, there were some species which were more habitat specific. For instance, *Chlaenius sericeus* Forst. and *C. alternatus* Horn were found mainly near wetlands. *Calasoma frigidum* Kirby was almost always found in traps near trees. *Carabus maeander* Fischer was usually collected in pasture or prairie. For these species, the maintenance of habitat diversity on the farm would increase the likelihood of occurrence of these habitat-specific species.

Spiders

In the survey, 179 spider species were collected including 18 undetermined species, plus one known from three Saskatchewan males, and one previously known only from the Rocky Mts. Probably half of the undetermined species are undescribed (D. Buckle, pers. comm.), reflecting the fact that little research has been done on prairie spiders. The results presented (Table 3) do not include those from Hatherleigh 1997, which were not complete at the time of publication. The variability in results was high but, in general, species richness was highest in both treed areas and in the large tract of native fescue prairie at Hatherleigh. Spider abundance was lower in cultivated areas. Although spiders are often highly mobile, especially in early developmental stages when they drift on winds using silken threads as parachutes, this study indicates that the high degree of disturbance caused by till agriculture is not conducive to high spider numbers or diversity. A similar result was found by Doane and Dondale (1979). They found higher spider species richness and evenness in field margins than in wheat fields near Saskatoon.

The wind protection, structure, plant diversity and lack of disturbance presented by trees, and to a lesser extent by native prairie, appear to be beneficial. In addition, many spider species have a strong habitat preference for trees. Shelterbelts harboured fewer species, however, comparable to cultivated areas.

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IMPROVING WILDLIFE HABITAT AT CRYSTAL SPRINGS COMMUNITY PASTURE

Dave Pochailo and Phil Curry

Ducks Unlimited Canada, Box 2139, Melfort, Saskatchewan S0E 1A0

Abstract: The Crystal Springs Community Pasture is a 5280 acre pasture near Birch Hills, Saskatchewan. Prior to 1994, management practices negatively affected the pasture's ability to support wildlife. Many of the natural wetlands had been drained, wetland fringes and adjacent uplands were heavily impacted by grazing while many other areas were under-utilized. Water quality was poor.

In 1994 Ducks Unlimited Canada, in cooperation with Saskatchewan Agriculture and Food, restored 91 small wetlands (326 acres) throughout the pasture. Thirteen kilometers of cross fencing subdivided the pasture into 20 paddocks. The 6 cattle herds were reduced to 5 and each herd was rotated through 4 fields on a once-over rotation. Animal numbers were marginally reduced from 1184 animals in 1994 to 1144 animals in 1995-97. Increased rest periods, varied timing of grazing, more uniform distribution of animals within fields and increased water quantity and quality have allowed the pasture to maintain its productivity for cattle while improving its value as wildlife habitat.

In 1997, surveys were conducted for waterfowl and grassland songbirds. Fourteen species of ducks were observed on the pasture with a pair density of 54.5 pairs/sq. mile. Blue-winged teal (*Anas discors*) was the most abundant species (14 pairs/sq. mile) followed by mallard (*Anas platyrhynchos*) at 8.25 pairs/sq. mile. Broods of eight duck species were observed. Breeding pairs of songbirds observed included savannah sparrow (*Passerculus sandwichensis*), vesper sparrow (*Pooecetes gramineus)*, clay-colored sparrow (*Spizella pallida*), le conte's sparrow (*Ammodramus leconteii*), song sparrow (*Melospiza melodia)*, bobolink (*Dolichonyx oryzivorus*), sedge wren (*Cistothorus platensis*) and horned lark (*Eremophila alpestris*). Savannah and vesper sparrows were observed to fledge young.

INTRODUCTION

The Crystal Springs Community Pasture is a 5280 acre parcel of land located near Birch Hills, Saskatchewan. Prior to 1994, the pasture was divided into 11 grazing paddocks with livestock separated into 6 herds according to breed and/or breeding status. The pasture was managed under season long or 2 paddock switchback grazing. Cattle were put into the pasture at the start of June and taken out at the end of October. There was no set rotation among fields from year to year. Most of the natural wetlands in the pasture had been drained and water quality was generally poor.

The large paddock size resulted in selective grazing by livestock. Wetland and wetland fringe areas were often heavily impacted by grazing while other areas were underutilized. Repeated overgrazing of some portions of the pasture was not only causing the pasture to deteriorate and become less productive, but it also negatively affected the pasture's ability to support wildlife. Very little residual vegetation was present in the wetland or wetland fringe areas in the spring. Waterfowl and other ground nesting birds were adversely affected by the lack of nesting cover available within the pasture.

Ducks Unlimited Canada, and Saskatchewan Agriculture and Food agreed to implement a grazing system in the pasture and to restore many of the drained wetlands. The objective was to maintain the pasture's productivity for cattle while improving its value as wildlife habitat.

PASTURE IMPROVEMENTS

In the fall of 1993 Ducks Unlimited Canada restored 91 small wetlands totaling 326 acres (Figure 1). Thirteen kilometers of cross fencing were built to subdivide the pasture into 20 grazing paddocks. Six new dugouts were constructed to ensure a water supply in all

Figure 1. The Crystal Springs Community Pasture

paddocks and to reduce livestock dependency on wetlands for watering. Three wetlands were fenced to exclude livestock. Three hundred acres of pasture in poor condition was re-seeded in the spring of 1994.

The original six herds were reduced to five and animal numbers were marginally reduced from 1184 in 1994 to 1144 in 1995-97. Each herd is rotated through four fields on a once over rotation. Fields grazed early one year are not grazed until later the following year.

BENEFITS

The implementation of the grazing system has resulted in more uniform distribution of animals within paddocks. Increased rest periods for the grass between grazing and variations in the timing of grazing allow the grass more time to recover from the effects of defoliation. In combination with improvements in water quantity and quality, this has allowed the pasture to sustain the previous level of grazing, improve the condition of the pasture, and provide better habitat for wildlife.

Restoration of 91 wetlands has resulted in more water for cattle and wildlife. While only three wetlands were fenced off exclusively for wildlife use, the grazing system has helped reduce the impact of grazing on the wetlands by reducing exposure, and varying the timing of grazing. The wetlands and wetland fringes have more time to recover from the effects of grazing. The vegetation associated with the wetlands and wetland fringe is therefore able to provide better quality habitat for wildlife.

The once over grazing rotation, and altering the rotation order so that the paddock grazed first in one year is grazed last the next year, provides over a year of rest for these paddocks. This allows the pasture vegetation to recover from the effects of grazing. The amount of residual vegetation available in the spring in any paddock varies from year to year depending not only on the timing and intensity of grazing, but also on environmental factors. The presence of residual vegetation in the spring provides important nesting cover for ground nesting birds. The deferral of grazing in some paddocks improves the quality of nesting cover.

In 1997, waterfowl pair counts and brood surveys were conducted over the entire pasture. Indicated breeding pair counts for waterfowl were conducted over the space of three mornings (May 20, 23, and 26, 1997). Fourteen species of ducks were counted on the pasture (Table 1). Blue-winged teal was the most common species of waterfowl observed in the pasture, representing approximately 25% of the duck breeding population. Mallard and green-winged teal (*Anas crecca*) were the next most common, representing 15% and 14% of the waterfowl breeding population respectively.

Broods counts were conducted on five mornings between June 19 and July 17, 1997. All wetlands were surveyed at least twice. Broods of eight duck species were observed (Table 2). Other broods observed include Canada geese (*Branta canadensis*), American coots (*Fulica americana*), red-necked grebes (*Podilymbus grisegena*), horned grebes (*P. auritus*), and pied-billed grebes (*P. podiceps*). Approximately 55% of the duck broods observed were blue-winged teal. By the middle of July emergent vegetation growth in and around many of the wetlands greatly reduced the visibility of duck broods. Due to the poor visibility it was decided to discontinue the brood counts even though new broods were still being observed and two active nests (blue-winged teal and redhead [*Aythya americana*]) were found during the last brood count. So while the waterfowl pair counts provide a good estimate of indicated breeding pair densities within the pasture, the brood counts do not represent waterfowl production surveys, but rather they serve as an indicator of waterfowl production on the pasture.

Casual observations of nesting cover were made during the waterfowl surveys. Generally, the two

Table 1. Ducks observed on Crystal Springs Community Pasture.

Species	# of Breeding pairs	Relative Abundance (%)	Indicated breeding pairs/sq. mile
Blue-winged teal *(Anas discors)*	112	26	14.00
Mallard *(A. Platyrhynchos)*	66	15	8.25
Green-winged teal (*A. crecca)*	63	*14*	7.88
American wigeon *(A. americana)*	36	*8*	4.50
Gadwall *(A. strepera)*	26	6	3.25
Lesser scaup *(Aythya affinis)*	26	6	3.25
Bufflehead *(Bucephala albeola)*	25	6	3.13
Northern shoveler *(Anas clypeata)*	23	5	2.88
Ring-necked duck *(Aythya collaris)*	17	4	2.13
Redhead *(Aythya americana)*	11	3	1.38
Canvasback *(Aythya valisineria)*	11	3	1.38
Ruddy duck *(Oxyura jamaicensis*	10	2	1.25
Common goldeneye *(Bucephala clangula)*	9	2	1.13
Northern pintail *(Anas acuta)*	2	0	0.13

Table 2. Duck brood observations in Crystal Springs Community Pasture for 1997.

Species	# of Broods	Relative Abundance (%)
Blue-winged teal	17	57
Mallard	4	14
Bufflehead	4	14
Green-winged teal	1	3
Redhead	1	3
Common goldeneye	1	3
Lesser scaup	1	3
Northern shoveler	1	3
Total Duck Broods	30	100

paddocks grazed earliest the previous year had a moderate to good quality of available residual vegetation for waterfowl nesting cover early in the spring, while the two paddocks grazed later had poor to moderate nesting cover. As cattle were moved into paddocks, grazing effects became apparent, and little nesting cover was available by the time cattle were moved to the next paddock. By the time the last brood count was carried out on July 17, vegetation was dense and nesting cover was rated as good to excellent on two of the four paddocks in each system.

Surveys of grassland songbirds were conducted in the four most northerly paddocks of the pasture (Figure 1) which comprised a complete grazing system for one herd of cattle. Four plots, each with a 100 meter radius, were established in the four paddocks. Each plot was visited twice during the breeding season (June 19 and July 12, 1997). Two of the paddocks were not grazed during the survey, one was grazed prior to the first visit and the fourth paddock was grazed during the time of the surveys.

Eight species of songbirds were observed in the plots (Table 3). All eight species were observed in the ungrazed paddocks, with only three species (savannah sparrow, vesper sparrow and horned lark) being found in the grazed paddocks. Savannah sparrow was the most common songbird observed and was the only songbird observed in all four paddocks. Savannah sparrows and vesper sparrows were observed to fledge young in the ungrazed paddocks. No songbirds were observed to fledge young in the paddocks that had been grazed.

Table 3. Indicated pairs of grassland songbirds by grazed and ungrazed paddocks.

	Paddocks			
	15a	14a	14b	15b
	Ungrazed		Grazed	
Species	Av. # / Plot*	Av. # / Plot*	Av. # / Plot*	Av. # / Plot*
Savannah sparrow	** 4.25	** 3.25	1.25	0.75
Vesper sparrow	0.5	** 0.75	0.25	
Clay-colored sparrow	1.25	1		
Song sparrow	0.25			
Le conte's sparrow	0.25			
Horned lark		0.25		0.5
Sedge wren	0.5			
Bobolink		0.25		
Number of species observed	6	5	2	2

* mean of 4 plots (100 m radius each) visited twice during the breeding period
** Evidence of fledgling success

Paddock 15a - Grazed 3rd (July 11 - August 8); vegetation density June 19 - dense
Paddock 14a - Grazed 4th (August 8 - Sept. 9); vegetation density June 19 - dense
Paddock 14b - Grazed 2nd (June 12 - July 11); vegetation density June 19 - moderate
Paddock 15b - Grazed 1st (May 28 - June 12); vegetation density June 19 - sparse

Table 4 illustrates the decline in savannah sparrows between visits in the paddock that was grazed during the survey period. During the first visit on June 19, nine pairs of savannah sparrows were observed, while on July 12, only one pair was observed. The cattle were put into this paddock on June 12 and taken out July 11. Vegetation density was moderate during the first survey on June 19 and poor by July 12.

Table 4. Decline in indicated pairs of savannah sparrows in Paddock 14b (grazed June 12 - July 11, 1997).

Plot #	19-Jun Pairs	12-Jul Pairs
Plot 1	3	1
Plot 2	2	0
Plot 3	3	0
Plot 4	1	0
Total	9	1
Mean	2.25	0.25

CONCLUSION

Increased rest periods, varied timing of grazing, more uniform distribution of animals within fields and increased water quantity and quality have allowed the pasture to maintain its productivity for cattle while improving its value as wildlife habitat.

LIVING IN THE LAND: BENEFITS OF RECONNECTING PEOPLE TO THE LAND THROUGH DIRECT INTERACTIONS WITH WILDLIFE AND WILD PLACES

Tina Portman and Rick Wyatt

Outreach Programs, Saskatchewan Association for Firearm Education, 1766 McAra Street, Regina, Saskatchewan S4N 6L4

Abstract: One problem in valuing nature is that people often consider themselves "visitors" to nature during outdoor activities or even "opponents" in many agricultural situations. This disconnection from nature fails to promote the biological reality that futures of land, wildlife and people are linked and therefore provides limited incentive for conservation of wildlife and habitat. Conversely, substantial evidence indicates that interacting with nature through hunting, fishing and trapping often leads to strong concern for wildlife and habitat. These activities require participation in the natural cycle of life and death and can foster a respect for wildlife that is impossible to reproduce in non-interactive and urban settings. Significantly, this concern translates into actions that conserve wildlife and habitat. Our prairie ecosystem may benefit from a change in philosophy among all outdoor activities that encourages people to become part of nature. Saskatchewan is piloting a unique program based on this philosophy, the Saskatchewan Outdoor Skills Training and Awareness Program (SOSTAP). Goals of SOSTAP are to promote outdoor awareness and ethics and increase participation in all outdoor activities by providing accessible training programs.

INTRODUCTION

The Saskatchewan Outdoor Skills Training and Awareness Program (SOSTAP) is an outdoor education program and network aimed at increasing public conservation awareness and participation in outdoor activities. Central to the program are principles that recognize intrinsic value of wildlife, interaction with nature as a means of feeling a part of nature, conservation awareness and outdoor activities as a way of life with a set of values to live by. SOSTAP promotes the future of Saskatchewan's wildlife and wild places by developing a network for increasing public awareness and outdoor education.

Education as well as sociology and philosophy are key disciplines in the interdisciplinary field of Human Dimensions research in conservation biology. Until relatively recently, conservation biology was exactly as it sounds - the science of biology applied to conservation of species. As more and more conservationists recognize the need for "people management," biology is partnering with education, sociology, philosophy and ethics. This need for human awareness and support for conservation is not new. Aldo Leopold, one of the first wildlife managers, concluded that [social] values such as love and respect are the dominant forces in establishing an "ethical relation to land" (Leopold 1966).

Education and awareness are goals in Canada's Biodiversity Strategy (Environment Canada 1995). The Strategy outlines both the importance of conservation of all species and benefits of conservation to all species. The Strategy brings the many faces of conservation together in an ambitious vision statement promoting a society that "lives and develops as a part of nature, values the diversity of life, takes no more than can be replenished and leaves to future generations a nurturing and dynamic world, rich in its biodiversity." To support and promote this vision the Strategy outlines five goals. The third goal is to "promote an understanding of the need to conserve biodiversity and use biological resources in a sustainable manner."

Human Dimensions researchers have also established the importance of education and communication in conservation. Communication among wildlife professionals (those whose work involves wildlife management decisions) and all wildlife users is considered vital for successful conservation by Mangel et al (1996). Fazio (1987) stressed the essential role that communication and awareness of habitat protection, the inter-relatedness of all species and the enrichment of quality of life by wildlife, among other things, must play in educating the public. Not only is awareness education important, but Kellert (1987) determined that it should go one step further - concern for wildlife must "move beyond feelings of compassion and kindness for selected animals to a conviction that the health and well being of wildlife and natural habitats are ultimately linked to human well-being and even survival." The question becomes: How can we best encourage and support the public in developing conservation awareness, hoping that they develop their own sense of ethics and perhaps conviction of interconnectedness?

Environmental education has its own section in libraries but it has many different approaches. Hair and Pomerantz (1987) concluded that direct wildlife experiences are integral to any wildlife education program. In a study of environmental leaders, Tanner (1980) found that 78% listed outdoor experiences as influencing their career choice. Within the realm of experiential education, emphasis can be placed on a range of philosophies, from no-impact, tip-toeing through the wilderness to minimum-impact encounters that encourage immersion in the wilderness and interaction through activities (hiking and fishing). At one end of the outdoor education gradient, people are "visitors," exemplified by Carl (1997) who describes turning a desire to build a fire into an "ecology lesson" in which dead wood, overhanging tree branches and roots become a natural microcosm where people and fire do not belong. At the other end are interactive programs that teach minimum impact skills - how to hike through wilderness safely, build fires and fish for rainbow trout (e.g. National Outdoor Leadership School, 1998). Minimum impact activities, including sustainable hunting, fishing, trapping and wild plant use, do not damage the resource or ecosystem beyond the natural boundaries of variation and therefore fall well within the guidelines outlined by Mangel et al. (1996) for conservation of wild living resources. There is also evidence that participation in interactive wildlife activities can be a means for people to move beyond Kellert's "compassion and kindness," enabling people to advance to feeling a part of nature (Decker et al. 1987).

People who participate in interactive wildlife activities have different reasons and goals for their involvement. Decker et al. (1987) proposed three main goals in wildlife participation:

1. Affiliative - participation in a wildlife activity is primarily for camaraderie.
2. Achievement - participation is based on meeting a standard of performance. Examples are hunting with a goal of meat or a trophy or birdwatching with a goal of finding and identifying a specific species.
3. Appreciative - involvement in the activity is for achieving a sense of peace, belonging and familiarity associated with the activity. [Kellert (1976) called this phase "Nature hunting" in his study of hunters. People in this phase hunted with the sole purpose of being in the outdoors and showed a strong concern and affection for nature.]

This third relationship with wildlife approaches the relationship between people and nature that Fazio (1987) and Kellert (1987) identify as important for public support and involvement in conservation. Decker et al. (1987) asserted that people's interactions in all wildlife recreation evolve towards an appreciative goal over time. This is supported by research in which many hunters began hunting with affiliative or achievement goals but tended to shift towards an appreciative goal during their lives (Decker et al. 1984, Purdy et al. 1985). The two essential steps in moving towards an appreciative involvement with wildlife activities are:

1. Voluntary adoption of a wildlife activity by an individual
2. Continual involvement in the activity - essential for the evolution of appreciative wildlife goals (Decker et al. 1987). "Continual involvement" implies that the activity of interest becomes a standard part of the participant's life.

This research suggests that an ideal conservation and outdoor education program should not only increase awareness. It should enable people to participate on a long-term basis in interactive outdoor and wildlife activities, allowing them to develop their own sense of outdoor and wildlife appreciation.

SOSTAP will provide this conservation education in two ways. First, SOSTAP will deliver courses to increase public awareness of conservation and biodiversity issues in the province. Second, SOSTAP will provide accessible interactive outdoor skills courses, from introductory to advanced levels for Saskatchewan people. Not only will this encourage people to try new outdoor activities, but through a multi-level accreditation system and hands-on skills learning, SOSTAP will also encourage continual involvement in outdoor activities. By increasing both public conservation awareness and public participation in outdoor skills and activities, SOSTAP hopes that conservation of wildlife and wild places will be a priority for people in Saskatchewan.

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AMPHIBIANS AND REPTILES ON THE ALBERTA PRAIRIES - CURRENT ISSUES

G.L. Powell and A.P. Russell

Dept. of Biological Sciences, University of Calgary, 2500 University Dr. NW, Calgary, Alberta T2N 1N4

Abstract: The Alberta Amphibian Monitoring Program now has over one hundred participants, scattered all across the province (north to south and east to west), with a standard protocol maintained through a monitoring guide and anuran call tape supplied by the Wildlife Division. The data gathered are to be used for species management and conservation projects, land use management and possibly an eventual Amphibian Atlas of Alberta. A similar effort is being made to establish a province-wide snake hibernaculum inventory. Prairie rattlesnake movement and population monitoring projects are currently being carried out by A.P. Russell's lab (University of Calgary) in partnership with the Medicine Hat office of the Wildlife Division, by the City of Lethbridge, and at Dinosaur Provincial Park; one has just been completed in Suffield National Wildlife Area by Andy Didiuk of the Canadian Wildlife Service. Provincial status reports have been released (northern leopard frog, short-horned lizard, and prairie rattlesnake) or are in preparation (Canadian toad, Great Plains toad, western hognose snake, and spotted frog) for all of the Blue Listed and Red Listed amphibian and reptile species in the province. These will be used in new status determinations by the Endangered Species Conservation Committee. As of September 1997 every amphibian and reptile species regarded to be at risk in the province is legislatively protected in one way or another. Future provincial initiatives include a plan to re-introduce northern leopard frogs into areas from which they had vanished; future intensive studies of Canadian toads and each of the three species of garter snake found in the province have been proposed.

INTRODUCTION

This paper discusses the current conservation initiatives affecting the prairie (mixed-grass and fescue) amphibian and reptile species found in Alberta. This does not constitute a comprehensive survey of the statuses of all of the province's prairie herpetofauna (this is currently under way - see below), but rather is a brief examination of what has and has not changed for these species since our last such summary (Powell and Russell 1996b).

AMPHIBIAN MONITORING

The Alberta Amphibian Monitoring Program (AAMP), a cooperative venture between the Alberta Conservation Association and Alberta Wildlife Management Services, now has almost one hundred participants, scattered across the province (Takats 1998), with protocol uniformity maintained through a monitoring guide and anuran call tape supplied by the Wildlife Management Services. Their reports are archived in the Biodiversity Species Observation Database (BSOD). A total of 710 records (of 9 species) were received in 1997, up from 675 (of 10 species) in 1996 (Takats 1998). *Croaks and Trills*, a newsletter distributed to all AAMP volunteers, summarizes yearly results and includes noteworthy amphibian news from Alberta and elsewhere. The data are to be used for species management and conservation projects, land use management and possibly an eventual Amphibian Atlas of Alberta. For the time being, data on abundance are not being collected in any standardized way, although any notes made on this (or anything else of biological interest) by correspondents are transcribed into the database. Currently, presence/absence data is used in determining species distributions (not necessarily well-known for all of Alberta's amphibian species), and for detecting sudden range diminutions. An initial analysis of the 1992 - 1994 data was produced by Powell et al. (1996a).

A project intended to produce intensive, long-term records of amphibian numbers at ecologically-representative sites across the province was initiated in 1997, although all of the sites so far are in the boreal forest. The RANA (Researching Amphibian Numbers in Alberta) project was initiated by Cindy Paszkowski and Brian Eaton, of the Dept. of Biological Sciences, University of Alberta, and efforts to begin monitoring Alberta prairie sites in the summer of 1998 have begun. This project explicitly serves a public-education function, and with sufficient time will increase our presently deficient knowledge of amphibian population phenomena.

SNAKES

An effort is being made by Alberta Wildlife Management Services to establish a province-wide snake hibernaculum inventory. Progress is sluggish; concerned with protecting vulnerable hibernacula, landowners and others aware of their localities are frequently reluctant to reveal them to anyone. This, however, does indicate an increasingly positive attitude towards snakes on the part of public.

Prairie rattlesnake (*Crotalus viridis*) movement and population monitoring projects are currently being carried out by A.P. Russell's lab (University of Calgary), in the vicinity of Medicine Hat, in partnership with the Medicine Hat office of the Wildlife Division; within the city limits of Lethbridge, by the City of Lethbridge (Reg Ernst and Liz Saunders); and at Dinosaur Provincial Park (by Parks, together with the Hanna office of the Wildlife Division). In addition, the Canadian Wildlife Service study of the snake fauna found within the Suffield National Wildlife Area, under Andy Didiuk, was completed in the summer of 1997. This study examined snake (wandering garter snake [*Thamnophis elegans vagrans*], prairie rattlesnake, bullsnake [*Pituophis sayi*], and western hognose snake [*Heterodon nasicus*]) population phenomena in a relatively little-used area, and will provide a valuable benchmark for similar studies carried out in areas with significant human activity. Increasing human population densities elsewhere in the rattlesnake's range on the Alberta prairies, plus a rise in the number of human uses even agricultural land is subject to, and increased human pressure on recreational land, have led to or will lead to greater pressure on rattlesnake populations. All three on-going rattlesnake studies are intended to provide data upon which management strategies can be based, appropriate to the land use typical of the area in which they are being conducted. A.P. Russell's study is also collecting data on bullsnakes, western hognose snakes, wandering garter snakes, and plains garter snakes (*Thamnophis radix*), and the Dinosaur Provincial Park study is collecting data on bullsnakes; however, the main focus of both studies is the prairie rattlesnake, as this is the species perceived to be under the most human pressure in this province (Watson and Russell 1997).

SHORT-HORNED LIZARDS

Janice James, of A.P. Russell's laboratory at the University of Calgary, recently completed a radiotelemetry study of the thermal biology of the eastern short-horned lizard (*Phrynosoma hernandezi*) in Alberta (James 1997).

NORTHERN LEOPARD FROGS

The northern leopard frog (*Rana pipiens*) does not appear to have recovered significantly from its catastrophic decline in the late 1970s (Wagner 1997). Ed Hofman of the Hanna office of the Wildlife Division continues to monitor a population at Princess Springs, which appears to be maintaining itself. Others are scattered around the southern part of the province, mainly in the mixed-grass prairie. These do not appear to be serving as sources for recolonization of areas from which the species vanished because of their wide separation, and due to the dryness of the area.

STATUS REPORTS AND LEGISLATION

The Wildlife Management Division of Alberta Environmental Protection released a revision of their *The Status of Alberta Wildlife* document (Anon. 1996), updating the information and statuses in the previous release (Anon. 1991) after prolonged consultation with workers in the relevant areas across the province. Several of Alberta's prairie amphibians and reptiles received new species statuses. The Canadian toad (*Bufo hemiophrys*) was upgraded from the Yellow List (sensitive, not currently at risk but may require special concern) to the Red List (at risk, believed to be declining or to have declined to non-viable levels). The western painted turtle (*Chrysemys picta*) has been downgraded from the Blue List (may be at risk, based upon current knowledge) to the Yellow B List (naturally rare and possibly requiring management attention). The eastern short-horned lizard and the western hognose snake have likewise been upgraded, from the Red List to the Blue List. The bullsnake and all three species of garter snake (wandering, plains, and red-sided [*Thamnophis sirtalis parietalis*]) have been upgraded from the Yellow List to the Yellow B List (bullsnake) and the Yellow A List (concern has been expressed over possible long-term decline - garter snakes).

Accompanying this initiative, the Wildlife Management Division is in the process of producing a series of provincial status reports. Three on Alberta prairie amphibians and reptiles have been released (northern leopard frog [Wagner 1997], short-horned lizard [James et al. 1997], and prairie rattlesnake [Watson and Russell 1997]), three are in the process of being written (Canadian toad [Hamilton et al. in prep.], Great Plains toad [James in prep.], and western hognose snake [Wright and Didiuk in prep.]), and one is planned for the plains spadefoot toad (*Spea bombifrons*). Detailed provincial status reports for all of the Blue

Listed and Red Listed prairie amphibian and reptile species in the province will thus be available shortly. These will be used in new status determinations by a ministerial advisory committee - the Endangered Species Conservation Committee - which will review formal designations of species which are endangered or threatened and will facilitate appropriate recovery planning and projects. Subsequent action will be a ministerial decision.

As of September 1997, the Canadian toad, the prairie rattlesnake and the spotted frog (*Rana luteiventris*) are classified as non-game species, and thereby provided with full protection, while the northern leopard frog has been classed as Endangered. Now every herpetile species regarded to be at risk in the province is protected in one way or another.

THE FUTURE

Liabilities associated with the collections of locality and habitat data represented by the provincial status reports and BSOD have been recognized, and access to such sensitive data as the locations of snake hibernacula is now being controlled. Tracking of changes in distribution, habitat use and abundance for the species in question can now be placed on a much firmer quantitative footing.

Proposed provincial initiatives include intensive studies of spotted frogs, Canadian toads, boreal toads (*Bufo boreas*), and each of the three species of garter snake found in the province.

We still feel that the guarded optimism we expressed in our last summary of the conservation status of Alberta's prairie amphibian and reptile fauna (Powell and Russell 1996b) is appropriate. While northern leopard frogs continue to languish and Canadian toads to decline in the aspen parkland, these issues are at least being examined now. Alberta's amphibian and reptile fauna have received a fair bit of official attention in the past few years, and the Non-Game Office and the Wildlife Management Division of Alberta Environmental Protection deserve a lot of credit for this. They have supported the province-wide low-intensity amphibian monitoring program, a series of definitive status reports (which also serve as reviews of what is known about the distributions and ecologies of the species in question), and intensive studies (short-horned lizard movement and habitat use [Powell and Russell 1996c] and movement, habitat use and numbers in a prairie rattlesnake population near Medicine Hat [Powell et al. 1998]).

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PLANT GENE RESOURCES OF CANADA

K.W. Richards and D. Kessler

Plant Gene Resources of Canada, Agriculture and Agri-Food Canada, Saskatoon Research Centre, 107 Science Place, Saskatoon, Saskatchewan S7N 0X2

Abstract: Plant Gene Resources of Canada (PGRC) is Canada's national plant seed genebank with a mandate to protect, preserve and enhance the genetic diversity of Canadian plants of economic importance and their wild relatives by acquiring, evaluating, researching and documenting plant genetic resources in order to provide fundamental genetic building blocks for crop variety development and plant genetic studies nationally and internationally. The genebank is a living collection of seeds and clonal material that is conserved through several methods for future use to solve breeding problems (pest resistance, drought), to provide material for new crop development or for evaluation in value-added processing. PGRC also preserves native plant material of the Canadian biodiversity including threatened and rare species. The multi-nodal system established in 1992 links rejuvenation, evaluation and documentation to research and plant breeding programs for specific crop plants. The Cereal Research Centre (Winnipeg) is responsible for wheat, oats and barley, Morden for hardy ornamentals, new crops and specialty crops, Fredericton for potatoes, Saskatoon for crucifers and forage species and Harrow for clonal material. Over 110,000 seed samples are preserved in PGRC and approximately 3,000 clonal accessions are housed at Harrow. Canada has responsibility for principal world base collections of barley and oats and for duplicate world base collections of pearl millet and oilseed and green-manure crucifers. PGRC has a number of research initiatives: analysis of genetic diversity; conservation methodology to better preserve germplasm and genetic diversity; and pollination requirements for many species in the collection so as to attain quantities of quality seed, aid breeding programs and conserve biodiversity. Emphasis is placed in obtaining and preserving native and unique plant material from across Canada which represents Canada's biodiversity.

INTRODUCTION

Canada's food supply is based on intensive agriculture and the benefits of plant breeding. Plant breeders through the process of directed evolution have created new cultivars possessing new combinations of genes, but with considerable genetic uniformity. As genetic uniformity increases, the potential for crop vulnerability to new pests, diseases, and environmental stresses also increases. As breeding goals change in response to changes in agricultural technology, pest infestations or market requirements, the plant breeders must search the pool of genes available. New gene combinations may be found within the present breeding population, but often the required genetic diversity must be obtained elsewhere. Genetic diversity gives us the sustained ability to develop new plant cultivars that can resist these pests, diseases, and environmental stresses. Wild ancestors and their relatives are the keys to genetic diversity. Traditionally, this diversity has been obtained from the centres of origin and the centres of diversity.

Genetic diversity, especially during the last 40 years, has been threatened by a number of forces. Genetic erosion at the centres of origin has been caused by new agricultural technology such as higher yielding but uniform crop varieties and a continually shrinking land base where wild plants grow resulting in many plant species and variants disappearing. Another force affecting genetic diversity is the narrow genetic base associated with some plant breeding methods.

Conservation of Canadian wild plant germplasm is also needed. Considerable material has been identified as unique to the Canadian biodiversity and as important to the original inhabitants of Canada. Some of this unique Canadian germplasm may be useful in crop diversification. Steps must be taken to preserve the genetic diversity of both crop and wild plant species, and to maintain its accessibility for future generations.

CANADIAN PLANT GERMPLASM SYSTEM

Plant germplasm conservation in Canada began as the result of a technical conference "Exploration, Utilization and Conservation of Plant Genetic Resources," sponsored by the Food and Agriculture Organization (FAO) of the United Nations in Rome in 1967. A meeting in Ottawa in 1968 convened by the Research Branch of Agriculture and Agri-Food Canada (AAFC) resulted in the recommendation that Canada develop a national policy on the permanent preservation of desirable germplasm. Agriculture and Agri-Food Canada appointed the first Plant Gene Resources officer, and established Plant Gene Resources of Canada (PGRC) in 1970. It was located on the Central Experimental Farm in Ottawa until early 1998 when it moved to a modern facility in Saskatoon, SK. The PGRC seed genebank, as part of the Saskatoon Research Centre, coordinates Canada's germplasm system and is Canada's main repository for seed.

The Canadian Clonal Genebank was designated in 1989 as the primary germplasm repository for fruit tree and small fruit crops. Originally located near Trenton, ON, it moved in 1996 to Harrow, ON.

The mandate of PGRC is to protect, preserve, and enhance the genetic diversity of Canadian plants of economic importance, and their wild relatives. This is done by acquiring, evaluating, researching and documenting plant genetic resources in order to provide fundamental genetic building blocks for crop variety development and plant genetic studies nationally and internationally.

Canada's Plant Germplasm System is a network of centres and people dedicated to preserving the genetic diversity of crop plants, their wild relatives, and plants present and unique in the Canadian biodiversity. The system plays a significant part of Agriculture and Agri-Food Canada's commitment to the Canadian Biodiversity Strategy in response to the UN Convention on Biological Diversity.

A multi-nodal system was established in 1992 to respond to recommendations from study committees on the enhancement of germplasm conservation in Canada. The system was initially funded through the Green Plan. This initiative links rejuvenation, characterization, evaluation, and documentation to research and plant breeding programs for specific crop plants. This strategy is consistent with recommendations of the FAO. The expertise of plant breeders is used to characterize, rejuvenate, and document the genetic diversity in collections. The Cereal Research Centre (Winnipeg) is responsible for cereals including wheat, oats, and barley. Hardy ornamentals, new crops and specialty crops are handled by the Morden Research Centre. The Fredericton Research Centre is responsible for potatoes, while the Saskatoon Research Centre is responsible for Crucifers and coordinates forage crop germplasm (both legumes and grasses) activities at the Semiarid Prairie Agricultural Research Centre (Swift Current) and at the Soils and Crops Research and Development Centre (Ste Foy).

In the multi-nodal system, the two central agencies, PGRC and the Canadian Clonal Genebank, are the primary contact points for germplasm entering and leaving Canada. They have responsibilities for national and international contacts, distribution, rejuvenation and evaluation of germplasm not assigned to the Nodes, seed viability testing, database management and technical information.

The multi-nodal system offers a number of opportunities for Canadian germplasm conservation. The rejuvenation of major species is being done at the plant breeding locations responsible for the species allowing PGRC and the Clonal genebank to concentrate on other preservation activities. Evaluations are being done by plant breeders, who have the expertise in the field, especially for specific traits such as disease resistance. This permits an accumulation of information on the accessions which is incorporated into the database for all to use. It also provides an opportunity for plant breeders to incorporate new genetic diversity into their breeding program.

WHAT THE COLLECTIONS CONTAIN

Plant germplasm is the living tissue from which new plants can be grown. Germplasm is usually seed, or it can be other plant parts —- a stem, a leaf, pollen, or even just a few cells that can be cultured into a whole plant. Plant germplasm contains the genetic information for the plant's hereditary makeup.

More than 110,000 seed samples are preserved at the Seed Genebank in Saskatoon. PGRC participates in the worldwide network of plant genetic resource centres established by the FAO and the International Plant Genetic Resources Institute (IPGRI). On Canada's behalf, PGRC has accepted formal responsibility for principal world base collections of barley and oats, and duplicate world base collections of pearl millet and of oilseed and green manure crucifiers. Canada's germplasm collection consists of about 43,000 accessions of barleys, 32,000 oats, 13,000 wheats, 4,000 forages (both legumes and grasses), 3,500 pearl millets, 3,000 vegetables (including 2,500 tomatoes), 1,500 crucifers and about 10,000 accessions of numerous species. There are 13 genera with more than 1,000 accessions and 28 genera with more than 100 accessions, which represent more than 98% of the collection. These genera are all well-known, highly domesticated major crops. It is apparent that much more collecting, acquiring and evaluation are needed for additional genera that might furnish diversification crops.

The seed collection includes foreign and indigenous plants, wild and weedy relatives of crop species, cultivars and inbred parental lines, elite breeding lines, genetic stocks, and some rare and threatened species. Genetic stocks will include induced and natural mutations, cytological stocks of genetic oddities and variations on normal chromosomes, marker genes, polyploids, and pest-resistant stocks.

Approximately 3,000 accessions are established at the Canadian Clonal Genebank in Harrow, ON. These include *Fragaria* (strawberry), *Malus* (apple), *Prunus* (apricot, cherry, nectarine, peach and plum), *Pyrus* (pear), *Ribes* (currant and gooseberry), *Rubus* (raspberry), *Rosa* (rose), *Sambucus* (elderberry), and *Vaccinium* (blueberry). Approximately two-thirds of the collection consist of indigenous wild relatives of Canadian fruit crops and the remaining one third consists of cultivars or breeding selections of Canadian origin or cultivars of interest to Canadian scientists.

CANADIAN GERMPLASM INFORMATION SYSTEM (GRIN-CV)

Canada uses a computerized database management system to assist in handling the massive amounts of data associated with the genetic resources. The database management system currently used, called the Genetic Resource Information Network-Canadian version (GRIN-CV) is based on Oracle, a relational database system running on an AAFC SUN workstation. For a number of years Canada was developing its own database management system, but recently obtained the powerful GRIN system developed by the United Stated Department of Agriculture. Now all of North America is on the same database management system and will facilitate future evaluations. The data is divided into three basic categories, passport (ie. origin of accession, donor), evaluation (ie. morphological, agronomic, quality, molecular characteristics), and stock management (ie. inventory and movement of accessions into and out of the collection). Researchers can learn about specific characteristics of each accession in the collection. All Nodes will interact with the database regularly, entering data, conducting searches, and so on. Interactive on-line services for clients on the Internet are planned for early fall 1998 and seed requests can also be made through the database.

GERMPLASM STORAGE

Prior to being placed into storage, seeds are evaluated for viability and dried to an optimum moisture content of 6-8% which takes 30-60d. Seed storage facilities at PGRC consist of long-term, medium-term, and cryopreservation units. For long-term storage, a large walk-in vault is available in which seed is preserved in sealed, laminated envelopes at -20° C. For medium-term storage, a large walk-in vault stores seed in paper envelopes at 4° C and 20% relative humidity. Cryopreservation (a type of freezing) in or over liquid nitrogen at -196° C is the most highly developed storage technique. Depending on species, dry seeds can last from a few years to centuries.

At the Canadian Clonal Genebank, clones are stored in the field, in screen houses or greenhouses. Scientists are also experimenting with cryopreservation of clonal material. Tissue culture techniques are well advanced and used for many species. Scientists are evaluating these techniques for those species that can't be stored by other means. Tissue culture is a cloning method — growing a whole plant from a small plant part in an artificial medium in a controlled, disease-free environment. Tissue culture is used extensively at the potato node in Fredericton for storage and distribution of germplasm.

GERMPLASM EVALUATION AND REGENERATION

Canada's multi-nodal system offers a number of opportunities for Canadian germplasm conservation. The rejuvenation of the major species is done at the plant breeding locations responsible for the species, allowing the central agencies to concentrate on preservation technology, genetic diversity analysis in the collections, germplasm distribution, database development. PGRC is also responsible for rejuvenation and evaluation of species not assigned to the Nodes. Characterization is done by plant breeders and technicians who have expertise with the plants. This permits an accumulation of relevant information on accessions for which there is currently insufficient information. Germplasm is evaluated for a number of desirable agronomic traits such as time to maturity or winter hardiness, resistance to pests, diseases, and environmental stresses, and quality factors such as chemical composition, colour and flavour. The results are made available through the national database.

EXPERT COMMITTEE ON PLANT AND MICROBIAL GENETIC RESOURCES

The Expert Committee on Plant and Microbial Genetic Resources reports to the Canadian Agriculture Research Council/Canada Committee on Crops (CARC/CCC) and advises on national plant genetic resource policies and activities. It draws its representation from Canadian federal and provincial government agencies, universities, industry, scientific societies, and non-government organizations. Specifically, the committee discusses and advises on the activities of the national program in plant genetic resources, makes recommendations to CARC on issues relating to plant and microbial genetic resources, and participates in the formulation of national plant and microbial genetic resource policy and its relationship to international programs.

GERMPLASM USERS

The Canadian Plant Germplasm System is devoted to the free and unrestricted exchange of germplasm with all nations and permits access to Canadian collections by any person with a valid use. Normally, this means plant breeders and researchers, but others such as medical researchers and educators are welcome.

Canada is very conscious of the fact that no country can pretend to preserve on its own all of the genetic diversity needed for all of its crop plants for all time. Our country recognizes the need to coordinate and share the work of conservation among countries. Canada strongly supports and effectively participates in international collaboration programs to this end, particularly the crop networks established with the assistance of the International Plant Genetic Resources Institute.

BENEFITS DERIVED FROM THE USE OF PLANT GENETIC RESOURCES

Plant genetic resources have been used in Canada for more than a century. All Canadians have benefited from their use through increases in the quantity and quality of food consumed. Benefits from their use have accrued through genetic improvements that have contributed to major increases in productivity and resistance to pests, diseases, and adverse growing conditions. Canadian grain yields have increased steadily over the past four decades, and the improved quality of our products has contributed to their prestige on world markets. Canola exemplifies Canada's contribution to enriching the world's crop diversity as a result of our use of germplasm acquired from other countries. In recent times, for example, wide crossing in *Hordeum* has the potential to increase salt and drought tolerance; native plums have been used to improve adaptability of domesticated plums; *Fragaria chiloensis* is better able to withstand drought; and many species of *Rubus* carry useful traits, including resistance to major fungal pathogens and insect pests. Shrub roses have been developed that are hardy to zone three and these are being widely grown, replacing the tender hybrid tea and floribunda roses. Many grass genera are adapted to xeric conditions due to drought and/or salt tolerance, while others are better adapted to more mesic conditions. Researchers continue to evaluate germplasm for new crop development and for improvements in value-added processing.

Crop diversification continues to be of significant concern to agriculture in Canada. Crop diversification is usually achieved through the adaptation of established crops to new production areas or through the new uses of plant constituents of well-known crops. With such crops there is reasonable probability of success because of established markets and the availability of already-developed germplasm, which can be further improved. By contrast, crops that appear to require costly, long-term breeding and market investment are considered economically risky, and there is limited incentive to develop the necessary genetic resources for their improvement. In Canada, priority would seem to be justified for additional investment in acquiring genetic resources related to crop diversification for some native forages, native fruits, biomass crops, wild rice, and greenhouse herbs. These diversification crops should be considered as they may place Canada in a competitive advantage with respect to cultivation and marketing.

Benefits are also derived by conserving Canada's biodiversity of indigenous plant species. In addition to commonly occurring species, threatened, rare, or endangered species are made available for study or for small habitat restoration projects.

Three tools are needed to improve the use of Canada's plant genetic resource collection: better knowledge about the characteristics of germplasm accessions, making this knowledge more accessible to germplasm users, and germplasm enhancement programs that integrate new genes and traits into genetic backgrounds that are more easily used by plant breeders.

FUTURE RESEARCH AND NEW DIRECTIONS

PGRC is actively expanding the germplasm collection to include native and unique plant species occurring across Canada. This initiative will help preserve Canada's genetic diversity (biodiversity) and will include rare and endangered plant species. This forms part of Agriculture and Agri-Food Canada's commitment to conserving Canada's biodiversity as expressed in its Action Plan. Priority is being placed on five regions: Lower Mainland area, BC; greater Okanagan area, BC; Palliser triangle, Alberta, Saskatchewan, Manitoba; Carolinian area, Ontario and Gaspe area, Quebec; and Annapolis Valley, Nova Scotia. These regions have been identified as at greatest risk to loss in biodiversity in a 1996 modelling risk analysis report by Environment Canada. Information on threatened species is also being provided by federal plant taxonomists. Taxonomic and distribution information from the Conservation Data Centres may also be used.

PGRC is increasing the use of modern, biotechnical procedures to analyse the genetic diversity of plants in the collection, and to determine the natural genetic diversity in a species's gene pool. This research will include a comparative analysis of phenotypic and molecular traits to determine the amount of genetic variation present and its distribution among accessions and individual genotypes. This information will be used to identify gaps in the collection and provide suggestions where we should be looking to fill these gaps. The research will also identify the degree of similarity between individual genotypes in an accession or among accessions in the collection permitting the establishment of a core collection for some crop species. This will provide useful information for taxonomic and evolutionary analyses. Plant breeders will be provided with information on useful variation to be incorporated into their programs.

Research is being initiated to understand the pollination requirements of various plant species in the collection. This will be done to enhance seed production, maintain genetic purity of accessions, and to assist plant development and conservation efforts. Obtaining sufficient quantities of quality seed from cross-pollinated plant species was identified as one of the major limiting factors in the management of world collections, as identified in a recent FAO report on the status of world collections.

Research is to be conducted on improving the preservation (storage) of the germplasm in the collection. Comparisons will be made of the germinability of seeds of different plant species preserved in medium-, long-term or cryopreservation and the economics of these versus other methods of preservation.

PREDATOR EXCLOSURES TO INCREASE PIPING PLOVER (*Charadrius melodus*) REPRODUCTIVE SUCCESS

Isabelle M. Richardson

Dept. of Renewable Resources, University of Alberta, 7-51 General Services Building, Edmonton, Alberta T6G 2M7

Abstract: During the summers of 1996 and 1997, two lakes in east-central Alberta and one in west-central Saskatchewan, were systematically surveyed for piping plovers. As breeding adults and subsequently nests were found, 32 of 68 nests were treated with small predator exclosures. Hatching dates were estimated for every nest in order to facilitate colour banding. In order to accurately evaluate fledging success, the hatched young of every nest were colour banded with unique combinations. No treated nests (0/32) were lost due to predation while 63.9% (23/36) of control nests were predated. Although research techniques were identical in both years, severe weather was a factor in 1997 and hatching success was significantly higher in 1996 (82%, 14/17) than in 1997 (47%,7/15) (χ^2=4.500, 1 df, $0.025<P<0.05$). Daily survival rate was significantly higher for treated (DSR=0.9846) versus untreated (DSR=0.9561) nests. Mean fledged young/pair was significantly higher for treated nests (1.09 chicks/pair) than control nests (0.50 chicks/pair) (t=-2.0509, 66 df, $0.01<p<0.025$). The results suggest that predator exclosures reduce predation of piping plover nests, and increase reproductive success.

INTRODUCTION

The piping plover (*Charadrius melodus*) is a small migratory shorebird which inhabits beaches, alkali flats and sandflats in North America. Three breeding populations have been identified: the Atlantic population breeds along the Atlantic coast from North Carolina to southern Canada; the Great Lakes population; and the prairie population breeds in the northern Great Plains from Nebraska to the southern part of the Canadian prairie provinces (Haig 1992). Due to a general decline in population in 1985, the piping plover was designated as endangered by COSEWIC (Committee on the Status of Wildlife in Canada).

The low reproductive success of the piping plover has been attributed to several factors including recreational use of nesting beaches (Haig and Oring 1985, Flemming et al. 1988, Melvin et al. 1994), habitat destruction (Haig and Oring 1985, Smith et al. 1993), environmental effects such as flooding (Prellwitz et al. 1995) and nest predation (Deblinger et al. 1992, Haig and Oring 1985, Smith et al. 1993). In the prairie population, nest predation has been identified as a significant limiting factor (Heckbert and Cantelon 1996, Whyte 1985, Richardson In prep.).

The use of predator exclosures to minimize predation on ground-nesting shorebird species, including the Atlantic population of piping plovers, has produced positive results (Deblinger et al. 1992, Estelle et al. 1996, Melvin et al. 1992, Post and Greenlaw 1988, Rimmer and Deblinger 1990, Vaske et al. 1994.) This study was designed to investigate the effectiveness of predator exclosures in reducing predation on piping plover nests in the prairies, while, in turn, increasing reproductive success.

STUDY AREA AND METHODS

The research was conducted on Killarney Lake, and the westernmost of the Reflex Lakes in south-eastern Alberta in 1996 and 1997 and, on Freshwater Lake in southwestern Saskatchewan in 1997. All three lakes are hyper-saline with beach substrate ranging from sandy to predominantly gravel. The predator exclosures used were, square-pyramidal in shape, made of four stucco wire panels with a bottom width of four feet, and a top width of two feet. The sides of the panels were attached together with the ends of the cut stucco wire, resulting in a free-standing square pyramid. Once an exclosure was placed over a nest, one re-bar, approximately the height of the exclosure, was placed at each of the four corners for stabilization. Each exclosure was secured in place by inserting two-60 cm nails, bent in half, into the ground on each of the four sides of the cage. Finally, to protect against aerial predators, the top of the exclosure was woven with bailing twine at 20 cm intervals. This design is based on recommendations made by Deblinger et al. (1992).

Beginning in early spring (May 1, 1996 and April 29, 1997), the study lakes were surveyed on foot for returning piping plovers by each of the two researchers. Each lake was surveyed every two days. Survey protocol followed the recommendations of Goossen (1990), and nest sites were mapped by aid of air photos. Nests were located by monitoring adult piping plovers with a spotting scope from a distance of approximately 50-70m (Goldin 1994). As nests were found, they were marked from several metres away. Clutch initiation date and approximate hatching date were determined by direct observation and back-dating of the egg-laying pattern based on a 34 day laying and incubation cycle (Haig 1992, Heckbert and Cantelon 1996).

Nests were sequentially designated as treatment (enclosed) or control as they were located. Treatment consisted of the two researchers placing the fully constructed exclosure over the nest, and securing each corner of the structure to the substrate with the re-bar and with the bent nails at the bottom. Total time elapsed for this procedure was recorded. After treatment, nests were observed for a maximum of two hours for the resumption of incubation. Eleven nests were revisited approximately every two days or less to check for predation, continuation of incubation and any other changes in status. Seventeen exclosures were erected in 1996, and fifteen in 1997.

To accurately determine hatching success, nests were monitored daily beginning three days prior to the estimated hatching date until hatching occurred. To accurately determine fledging rate, hatched young were captured by hand and colour banded with unique combinations corresponding to their individual nests. Aluminum bands were also placed on all banded birds. The chicks were returned within close proximity to the parents and care was taken to ensure parents did not lose sight of their brood at any time during the procedure. To minimize stress on young birds, banding was carried out during the cool part of the day and any inclement weather was avoided. This technique has been used by plover banders across North America and has been endorsed by the Prairie Piping Plover Recovery Team. Broods were monitored for survival until fledging at approximately 25 days of age (Haig 1992).

Daily survival rates were calculated using the Mayfield method (Mayfield 1975). A successful nest was defined as one hatching at least one of the eggs laid. Hatching success is the proportion of successful nests and productivity is the number of young fledged/pair. Productivity was compared for treated and control nests using *t*-tests. Contingency table analysis (Zar 1984:64) was used to compare rates of predation, hatching success, and daily survival rates for treated versus control nests.

PRELIMINARY RESULTS

Thirty-two out of 68 nests were treated with predator exclosures during the two years of study. Treated nests had significantly lower predation rates than control nests ($P<0.001$). Predators destroyed 64% (20/37) of control nests, but had no known impact on treated nests. Predation was assumed to have occurred when eggs disappeared from a nest well before the expected hatch date and where no unaccounted-for young were in the surrounding area. In all cases, predation resulted in the disappearance of the full clutch of eggs. The appearance of the nest bowl after predation was typically messy. There were no mammalian prints in close vicinity to the bowl though on several occasions, what appeared to be avian footprints and claw marks were seen in or around the nest bowl but no egg fragments were ever found.

Daily survival rate for treated nests (0.9846, SE=0.00462) was significantly higher than for control nests (0.9561, SE=0.00895) (χ^2=9.1554, 1 df, $0.001<P<0.005$). Hatching success was 66% for treated nests (21/32) and 36% for control nests (13/36) (χ^2=5.903, 1 df, $0.01<P<0.025$). Although hatching success for treated nests was significantly higher than control nests, the results may underestimate the effectiveness of the exclosures in increasing hatching success due to destruction of exclosures by cattle and due to several late incubation abandonments of treated nests in 1997. Of the eight treated nests that failed in 1997 (n=15), one was caused by an adult being killed by a predator directly outside the exclosure (the clutch remained complete and intact), one abandonment was related to severe cattle trampling around the exclosure and one was an unexplained late incubation (2-3 days prior to hatch) abandonment. The remaining five failed nests were abandonments ranging from six to 21 days after clutch initiation and after both parents were seen incubating after the application of the exclosures. All five nests were initiated before May 21 when the study area experienced snow and below freezing temperatures. All six abandonments occurred after May 21. Although research techniques were identical in both years, hatching success was significantly higher in 1996 (82%, 14/17) than in 1997 (47%, 7/15) (χ^2=4.500, 1 df, $0.025<P<0.05$). Mean fledged young/pair for treated nests was significantly higher (1.09 chicks/pair) than for control nests (0.50 chicks/pair) (t=-2.0509, 66 df, $0.01<p<0.025$).

CONCLUSIONS AND RECOMMENDATIONS

It is clear that predator pressure is high on Reflex and Killarney Lakes. In this study, predator pressure was assumed to be coming from aerial predators as no mammalian prints were ever seen in close proximity to destroyed nests. Adult piping plovers invariably returned to incubate eggs within the exclosures, and no nests were destroyed by predators once exclosures had been applied.

Cattle damaged five of the treated nests on Reflex Lake where cattle are grazed on adjacent land (four of these resulted in nest abandonments). In all five cases, the damage occurred in mid-summer when deer flies (Diptera: Tabanidae: *Crysops* spp.) and horse flies (Diptera: Tabanidae: *Hybomitra* spp.) are abundant, and when cattle may be looking for something to scratch on. In order for exclosures to be successful, cattle should be restricted from nesting areas during this time. Electric fencing may be an effective method to achieve this.

One adult plover was killed directly outside of an exclosure two or three days prior to the hatching date. Although this is the only case of adult predation observed during this study ($\bar{x}$=68 nests), Murphy et. al. (in prep.) have witnessed several such mortalities in the Great Plains. It is recommended that if using exclosures, they should be monitored frequently in order to become aware of any occurrence of adult predation as soon as possible.

Colour banding was successfully carried out with only one case of injury assumed to be caused by banding. Although the bird was seen limping, no swelling was apparent on the banded leg. The juvenile survived beyond the fledging date but was not seen thereafter. Nevertheless, colour banding was very useful in assessing fledging rate for individual nests as band combinations made identification of chicks unmistakable. As the young birds aged, colour bands also became invaluable when discerning the identity of juveniles in mixed feeding groups.

Undoubtedly, predator exclosures are very effective in protecting nests against predation. Although nest success for treated nests during 1997 was low; the reason for this is thought to be the severe weather experienced while the nests were early in incubation. Even with such a low success year taken into consideration, hatching rates were significantly improved through the use of exclosures over the two years of the study.

A protocol document on the use of predator exclosures was developed as a result of this research. The document "Guidelines for the use of predator exclosures to protect piping plover nests" (Richardson 1997) sets out guidelines for the construction, application and monitoring of the exclosures. As a preliminary step in a province-wide piping plover conservation initiative, this document will minimize the *ad hoc* use of predator exclosures thus minimizing impacts on the birds.

Predator exclosures are effective in protecting piping plover nests from predation. Severe weather will occur during some years affecting nesting success regardless of conservation initiatives. Although predator exclosures are not a long-term or permanent solution towards achieving a stable piping plover population, they are, in some cases, a useful tool in attaining local/regional population goals while key limiting factors are being researched.

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EPIDEMIOLOGY OF A NEWLY IDENTIFIED IRIDO-LIKE VIRAL PATHOGEN IN TIGER SALAMANDERS IN SASKATCHEWAN, CANADA.

Danna Schock and R. Mark Brigham

Biology Department, University of Regina, 3737 Wascana Parkway, Regina, Saskatchewan S4S 0A2

Trent Bollinger

Canadian Cooperative Wildlife Health Centre, Toxicology Research Centre, 44 Campus Drive, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5B3

Abstract: The ecology of amphibian diseases is poorly understood. Even the causative agents of most amphibian diseases are still unknown. Recently viruses, and in particular iridoviruses, have been implicated in several amphibian diseases. Iridoviruses identified as amphibian pathogens have been shown to be pathogenic to more than one species and Bohle's Iridovirus has been shown to be pathogenic to fish and amphibian hosts. During the course of field work in 1997, a number of sick/dead tiger salamanders (*Ambystoma tigrinum*) were found in the Regina, SK area. Results of gross, histological and microbiological examination of the dead salamanders suggest an iridovirus as the cause of disease. Identification of this viral disease raises several questions. Is this a new disease and if so, how was it introduced into these ponds? How does the disease spread within a pond and from pond to pond? If this is not a new disease but occurs naturally in tiger salamander populations, is it involved in local or regional amphibian population declines? Which species, including fish species, are susceptible? Is fish translocation and stocking of ponds involved in spreading the disease?

To address these questions, research undertaken in 1998 will have four goals: 1) Determine if disease reoccurs in ponds affected in 1997. 2) Describe the epidemiology of the disease (i.e. species affected, age classes affected, temporal and spatial occurrence of disease, etc.). 3) In conjunction with the field research, confirm susceptibility of various hosts by laboratory infection trials as well as development/improvement of diagnostic tests for this disease. 4) In collaboration with other researchers, characterize this virus using molecular techniques and compare it to isolates from other parts of the world.

INTRODUCTION

Since the late 1980's there has been growing concern over the world-wide decline in amphibian populations. Habitat loss has been acknowledged as one causative factor; however, the disappearance of and drastic declines in some populations of amphibians, where suitable habitat appeared to remain, indicates other factors may be responsible for the declines (e.g. Barinaga 1990, Blaustein and Wake 1990, Carey 1993). While diseases of amphibians and the role they may play in local or regional population declines are poorly understood, there is mounting evidence that viral pathogens, and in particular iridoviral pathogens, may be a key factor involved in amphibian population declines (e.g. Cullen et al. 1995, Speare and Smith 1992 and references therein).

In Canada, amphibian populations are declining in many regions. On the prairies, the Northern Leopard Frog (*Rana pipiens*) has been of special concern since it disappeared from much of its range in the late 1970's. The decline was rapid and the cause is still unknown. Prior to recognition of the dramatic decline, localized high mortality was attributed to the disease 'red-leg'. Red-leg is frequently diagnosed in amphibian die-offs but its cause is not well understood; the name describes the typical lesions rather than indicating a specific disease agent. Although red leg disease has long been thought to be caused by opportunistically pathogenic bacteria such as *Aeromonas* and *Acinetobacter,* Cunningham et al. (1996) found evidence suggesting that redleg outbreaks in the common frog (*Rana temporaria*) may in fact be the result of a primary infection by an iridoviral pathogen with secondary infections of

Aeromonas setting in once an animal's immune system is already compromised.

Iridoviral Pathogens of Fish and Amphibians

Many of the viruses identified as pathogens in amphibians and fish are closely related members of the family Iridoviridae (Ahne et al. 1997, Mao et al. 1997). Characteristics shared by iridoviruses include icosahedral shape, a single linear molecule of double-stranded DNA, and assembling of virions in the cytoplasm (Darai 1990, Murphy et al. 1995). While the role of iridoviruses in redleg outbreaks is still somewhat putative, there are several confirmed iridoviral pathogens of fish and amphibians. Epizootic haematopoietic necrosis virus (EHNV) has been shown to be pathogenic to several teleost fish species including redfin perch (*Perca fluviatilis*), rainbow trout (*Oncorhynchus mykiss*), and mountain galaxias (*Galaxialis olidus*) (Langdon 1989). Frog erythrocytic virus (FEV) has been shown to be pathogenic to bull frogs (*Rana catesbeiana*), green frogs (*Rana clamitans*) and mink frogs (*Rana septentionalis*) (Gruia-Gray and Desser 1992). At least one iridovirus has been conclusively shown to jump between piscine and amphibian hosts. Speare and Smith (1992) first isolated and identified Bohle Iridovirus (BIV) as a pathogen in the ornate burrowing frog (*Limnodynastes ornatus*) in Australia. Moody and Owens (1994) demonstrated that BIV is pathogenic in barramundi fish (*Lates calcarifer*) and Cullen et al. (1995) demonstrated that BIV is pathogenic in *Bufo marinus*, *Limnodynastes terraereginae* and *Litoria latopalmata*.

Viral Disease in Tiger Salamanders in Arizona

Jancovich et al. (1998) recently found evidence that a virus is the primary pathogen involved in periodic decimating epizootics in Sonora tiger salamanders (*Ambystoma tigrinum stebbinsi* Lowe). Based on viral morphology and host pathology the virus is believed to be an iridovirus. This virus is the first lethal epizootic virus reported from salamanders.

Viral Disease in Tiger Salamanders in Saskatchewan

During the spring and summer of 1997, several dozen ill/dying tiger salamanders (*Ambystoma tigrinum diaboli* Dunn) were found at a number of small water bodies near Regina, Saskatchewan. Salamanders which had been collected and moved to a lab facility subsequently died and caused a severe die-off in an existing collection of tiger salamanders. Necropsies of the dead salamanders revealed severe liver necrosis, enteritis and ulcerative dermatitis associated with viral inclusion bodies. The virus has been isolated with tissue culture using a fish-cell-line and, based on transmission electron microscopy, appears to be an iridovirus.

The detection of this disease and isolation of the virus raises several questions: Is this a new disease and if so, how was it introduced into these ponds? If it is not a new disease but occurs naturally in tiger salamander populations, does it play a role in local or regional amphibian population declines? Which species are susceptible and in particular can fish be infected? How does the disease spread within a pond and from pond to pond? Does fish translocation and stocking of ponds play a role in spreading the disease? Based on the knowledge that nearly all other described iridoviral pathogens infect multiple species, it is not unreasonable to suspect that this iridovirus may also infect multiple species.

RESEARCH GOALS

To begin answering some of the questions this new virus raises, research conducted in 1998 will have four main goals: 1) To determine whether disease reoccurs in ponds affected in 1997. 2) To describe the epidemiology of the disease. 3) In conjunction with the field research, to confirm susceptibility of various hosts by infection in the laboratory and develop and improve diagnostic tests which can be used for this disease. 4) In collaboration with Dr. Chinchar of the University of Mississippi Medical Center, to characterize this virus using a variety of molecular techniques and hopefully compare it to isolates from other parts of the world, including the iridovirus isolated from tiger salamanders in Arizona.

Goals 1 and 2 make up the bulk of this project. These goals will be addressed by routinely sampling tiger salamanders from four water bodies for the presence of the virus. Two ponds are sites where disease was found and virus isolated from the salamanders in 1997. The other two ponds are sites were there were no signs of disease in 1997, these ponds acting as control ponds. The first sampling period will occur soon after first thaw in order to sample adult salamanders that have successfully overwintered. Samples of salamander eggs as well as a one-time sample of adult wood frogs (*Rana sylvatica*) will also be taken in during this sampling period. A second sampling period will occur in mid to late June, a point in the season when larvae and adults are simultaneously found in ponds; both larvae and adults will be sampled. The third sampling period will occur in late July - early August when larvae are metamorphosing and preparing to leave the ponds; larvae/metamorphosing salamanders as well as any adults encountered will be sampled. This sampling schedule will afford an opportunity to determine if animals harbour the virus over winter, if there is a certain life stage that is more susceptible than another (eg. larva vs. juvenile vs. terrestrial adult) as is seen with FEV (Gruia-Gray and Desser 1992) and BIV (Cullen et al. 1995), and if there is a particular time of the season when the disease is more prevalent. Wood frogs will be sampled during the first sampling period as it is during this time that the two species are both breeding at the ponds and likely to be in closest contact with each other. If there is any transmission of disease between the two species, it is at this time that transmission is most likely to occur. In addition to the routine sampling, any ill/dead animals (piscine, amphibian or reptilian) encountered at field sites will be collected and examined for signs of disease and presence of the virus in question. In an attempt to identify geographical distribution of this virus, there will be an initiation of a serological survey of water bodies in Saskatchewan and possibly Alberta, Manitoba, Montana and North Dakota.

Detection of the presence of the virus in the animals sampled will be accomplished through virus isolation, viral neutralization and histological examination of tissue. The method of preservation of sampled animals will also afford the opportunity to inspect for some parasites (eg. intestinal parasites). Blood smears of each animal will be examined for indications of other diseases (eg. protozoa, other types of virus).

Research addressing Goals 3 and 4 is currently underway. In preliminary trials, healthy tiger salamanders injected with virus isolated from other tiger salamanders have developed the disease and died 14 days after inoculation. Infectivity trials will include tiger salamanders, chorus frogs (*Pseudacris triseriata*), wood frogs and various stocked fish species in the laboratory to determine potential hosts of this virus as well as routes of infection. Results of these trials will be contrasted with findings from the field.

SUMMARY

In 1997, a previously undescribed iridoviral-like pathogen was found in tiger salamanders in Regina, SK. Recent reports in the literature indicate that iridoviruses can cause severe disease in fish and amphibians with at least one virus, BIV, causing disease in both fish and amphibians. Based on this knowledge, the iridovirus found in tiger salamanders in Saskatchewan could be potentially important to fish stocking practices as well as to conservation strategies of native amphibian species.

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BIRD USE OF CONVENTIONAL, MINIMUM TILLAGE, AND ORGANIC FARMS

Dave Shutler, Adele Mullie, and Robert G. Clark
Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, Saskatchewan S7N 0X4
and
Department of Biology, University of Saskatchewan, 112 Science Place, Saskatoon, Saskatchewan S7N 5E2

Abstract: Although the amount of land devoted to various conservation farming practices continues to grow, little is known about how this affects wildlife. We compared avifaunas of conventional farms, conservation farms (minimum tillage and organic), and restored or natural (wild) sites in Saskatchewan, Canada. Of 37 upland bird species, one made greater use of farm sites, four made greater use of wild sites, and the remaining species showed no preference or were too infrequent for analysis. Combining upland species, more individuals were detected per census on wild than on farm sites, and more individuals were detected on minimum tillage than on conventional farms. Wild sites also had more upland species than did conventional farms, but Shannon diversity did not differ among treatments. Of 79 species using wetlands and their margins, seven made differential use of treatments, most being more common on either organic farms or wild sites. On wetlands and their margins, more individuals were detected per census on wild sites and organic farms than on minimum tillage or conventional farms. Wetlands of wild sites had more species and higher Shannon diversity than did minimum tillage or conventional farms. Most treatment effects could be ascribed to the difference between wild and farm sites, and to a lesser extent to possible ecological benefits of reduced chemical usage and reduced tillage. Although, relative to conventional farming, conservation farming enhanced avifaunas, restored and maintained native areas supported higher relative abundance and diversity of birds.

SPECIES OF CONCERN ON THE NORTH AMERICAN GREAT PLAINS AND THEIR OCCURRENCE ON NATIONAL GRASSLANDS

John G. Sidle

Great Plains National Grasslands, USDA Forest Service, 125 N Main ST, Chadron, Nebraska 69337 USA (email: jsidle/r2_nebraska@fs.fed.us)

Abstract: In the Great Plains of North America, most governments and some private organizations, maintain lists of animal and plant species experiencing declines and threats to their long term survival. Such species commonly are called endangered, threatened, species of special concern, rare, etc. I compiled the various lists of species from federal, provincial, and state governments, The Nature Conservancy, and other organizations with the view of understanding the role of Great Plains National Grasslands in conserving species of concern. Administered by the U.S. Forest Service, National Grasslands comprise 1.5 million ha (gross area, including adjacent private land and inholdings) of public lands from Texas to North Dakota. Public lands of any kind make up a small percentage of the Great Plains, a region of over 200 million ha. Some 1,031 species are listed in one or more areas of the Great Plains. Five hundred twenty-two occur on one or more National Grasslands. Twelve are listed as endangered or threatened by the U.S. Endangered Species Act and six are candidates for listing under the Act. Seventy-one species occurring on National Grasslands are ranked by The Nature Conservancy as critically imperiled, imperiled, or vulnerable.

INTRODUCTION

The Great Plains region of North America stretches from northeastern Mexico to southeastern Alberta, Canada (Figure 1) and has undergone a tremendous transformation since settlement by Europeans. Traveling across the Great Plains or examining satellite images of this agricultural region reveals a terrain of platted farms and ranches devoid of many original, natural habitats. Aquatic habitats have been altered through ditching, instream flow withdrawal, channelization, filling, and erosion. Most of the prairie in the eastern and central Great Plains has been converted to cropland. The mixed and shortgrass prairies in the western Great Plains are among the last remaining large areas of grassland in the Great Plains. It is on this back drop of habitat changes that biologists have established various lists of species of concern in the Great Plains.

GREAT PLAINS SPECIES OF CONCERN

Federal, state, and provincial governmental agencies and non-governmental organizations (Committee on the Status of Endangered Wildlife in Canada [COSEWIC], International Union for the Conservation of Nature [IUCN], The Nature Conservancy [TNC], and Partners in Flight [PIF]) have attempted to list or rank species of concern, using various criteria, throughout all or a portion of the Great Plains. There is a total of 1,031 species, subspecies, or populations of concern to the agencies and organizations in the Great Plains (the complete 32-page matrix of species of concern and criteria for listing in the Great Plains can be seen on the Internet at site http://www.fs.fed.us/r2/nebraska/gpng). The total

Figure 1. The Great Plains of North America.

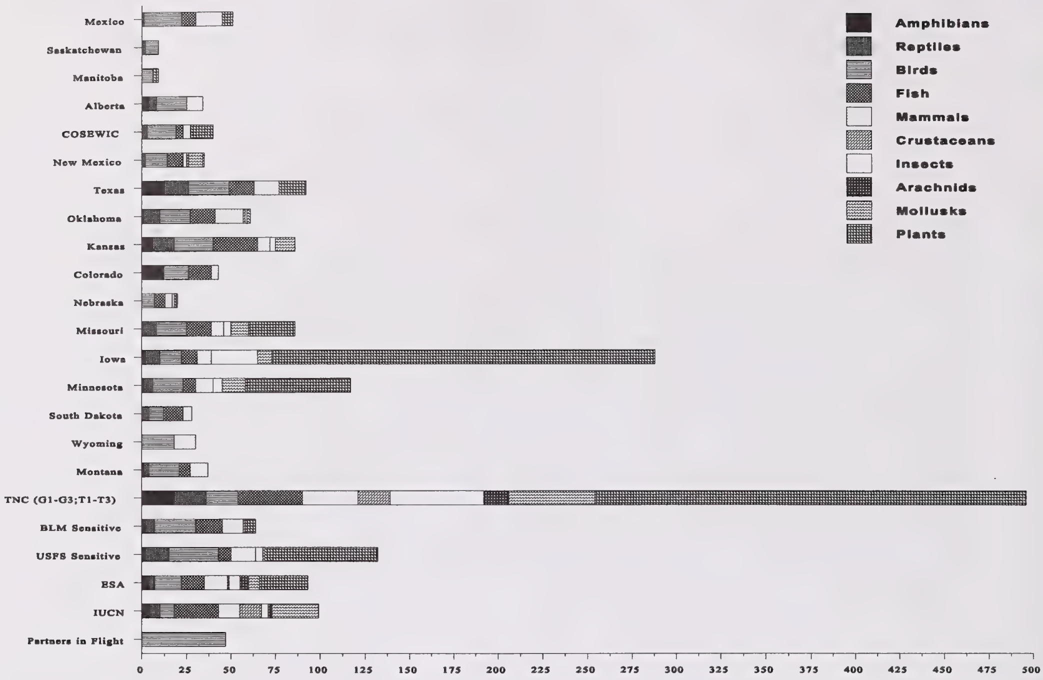

Figure 2. Number of species listed as threatened, endangered and of concern by the government of Mexico; number of species listed as threatened, endangered, and of concern by provincial and state governments, including COSEWIC and IUCN; number of species designated by The Nature Conservancy as G1-G3 or T1-T3 which are not covered by the above Canadian, Mexican, and U.S. federal and provincial/state designations); number of Bureau of Land Management (BLM) and USDA Forest Service (USFS) sensitive species; number of listed, candidate, and proposed species under the Endangered Species Act of 1973, as amended (ESA); number of Partners in Flight avian species of concern.

includes 444 plants, 46 amphibians, 65 reptiles, 122 birds, 96 fish, 82 mammals, 18 crustaceans, 82 insects, 14 arachnids, and 62 mollusks (Figure 2). However, this does not convey that each species is equally imperiled. U.S. states have different criteria for listing species. An uncommon listed species in one state may be abundant throughout the rest of the Great Plains. One state's politics and other factors may compel that state to list more species than another state. The river otter (*Lutra canadensis*) is listed by several Great Plains states but is ranked as globally secure (G5) by TNC. Buffalo grass (*Buchloe dactyloides*) is a species of concern in Iowa but is not in any danger of extinction in the Great Plains. Most of the PIF's highest priority, high priority, and moderate priority avian species are listed as apparently secure (G4) or secure (G5) by TNC. Some listings by governmental agencies and non-governmental organizations are an attempt to carry out conservation before species are in dire straits.

The U.S. Endangered Species Act (ESA) considers 85 Great Plains species endangered or threatened, or candidates for listing. The IUCN classifies nearly 100 species of concern in the Great Plains. TNC ranks 496 Great Plains species as G1-G3 or T1-T3 (Figure 3; Table 1). A G1 (critically imperiled) rank indicates a species with typically five or fewer occurrences, fewer than 1,000 individuals, less than 2,000 acres, or less than 10 stream miles, or some factor(s) making it especially vulnerable to extinction; G2 (imperiled) indicates a species with typically 6-20 occurrences, 1,000-3,000 individuals, 2,000 to 10,000 acres, 10-50 stream miles, or some factor(s) making it very vulnerable to extinction throughout its range; and G3 (vulnerable) indicates a species that is very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), with typically 21-100 occurrences or 3,000-10,000 individuals. T1, T2, and T3 mean the same, but refer to subspecies or varieties.

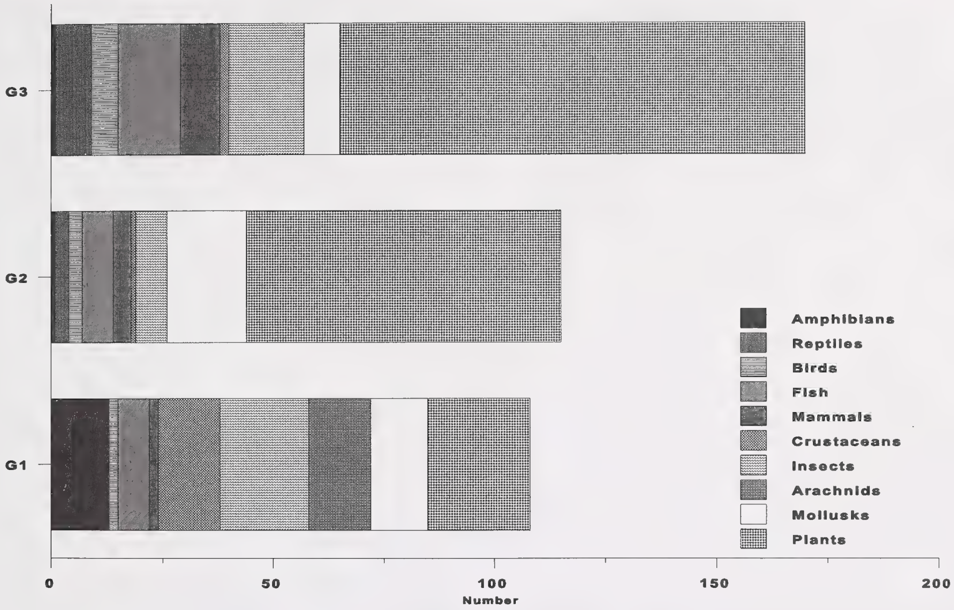

Figure 3. The number of critically imperiled (G1), imperiled (G2), and vulnerable (G3) species in the Great Plains as ranked by The Nature Conservancy.

There are 88 animals of concern that are endemic to the Great Plains (Table 2). The 88 animals include 18 amphibians, 7 reptiles, 5 birds (3 endemic as breeders only; 2 year long endemics), 5 mammals, 17 crustaceans, 18 insects, 14 arachnids, and 9 mollusks. Nearly 100 plant species and varieties are endemic to the Great Plains (Table 2). Most species of concern occur in the southern Great Plains, especially Texas, which also harbors the largest number of endemic species of concern.

NATIONAL GRASSLANDS

The Great Plains in the U.S. comprises over 200 million ha. National Grasslands (1.5 million ha) represent only 1% of the Great Plains. Several million acres of lands administered by the Bureau of Land Management (mostly in Montana, Wyoming, and New Mexico), National Park Service, and U.S. Fish and Wildlife Service also represent a small percentage of the Great Plains land base.

Great Plains National Grasslands are distributed from tallgrass prairie to shortgrass prairie ecoregions. They range in size from 586 to 416,000 ha (Table 3). Many National Grasslands are heavily fragmented (see Internet site http://www.fs.fed.us/r2/nebraska/gpng for maps of all National Grasslands). For example, the Black Kettle National Grassland (12,660 ha) is comprised of over 60 separate parcels. Such fragmentation hinders the adequate provision of habitat for some species and should remind us that all species cannot be protected on existing public lands in the Great Plains. Efforts at species conservation on private lands must prevail.

National Grasslands were purchased beginning in the early 1930's in response to the Dust Bowl drought and Great Depression economic conditions which were making private agricultural use untenable. Later, the Bankhead-Jones Farm Tenant Act of 1937 and subsequent amendments authorized the federal government to:

> develop a program of land conservation and land utilization, in order thereby to correct maladjustments in land use, and thus assist in controlling soil erosion, reforestation, preserving natural resources, protecting fish and wildlife, developing and protecting recreational facilities, mitigating floods, preventing impairment of dams and reservoirs, developing energy resources, conserving surface and subsurface moisture, protecting the watersheds of navigable streams, and

Table 1. Distribution of the 496 Great Plains species and subspecies globally ranked as G1-G3 or T1-T3 by The Nature Conservancy.

Province/State	Amphibians	Reptiles	Birds	Fish	Mammals	Total Vertebrates	Crustaceans	Insects	Arachnids	Mollusks	Total Invertebrate	Total Animals	Total Plants	Total G1-G3
Alberta	0	0	5	1	2	8	0	1	0	0	1	9	3	12
Saskatchewan	0	0	5	1	2	8	0	2	0	0	2	10	5	15
Manitoba	0	0	2	1	1	4	0	4	0	1	5	9	2	11
Montana	0	0	4	3	4	11	0	2	0	1	3	14	10	24
North Dakota	0	0	4	5	2	11	0	7	0	4	11	22	10	32
South Dakota	0	1	5	3	5	14	0	9	0	8	17	31	13	44
Nebraska	0	0	5	7	5	17	0	7	0	11	18	35	15	50
Wyoming	0	1	5	1	6	13	0	6	0	1	7	20	15	35
Colorado	0	1	6	1	6	14	0	13	0	0	13	27	21	48
Minnesota	0	0	2	4	1	7	0	8	0	17	25	32	7	39
Iowa	0	0	3	5	3	11	0	6	0	16	22	33	9	42
Missouri	0	0	1	6	3	10	0	8	0	17	25	35	10	45
Kansas	0	3	9	10	5	27	0	9	0	10	19	46	21	67
Oklahoma	0	3	9	9	7	28	1	7	0	14	22	50	21	71
New Mexico	0	2	5	11	5	23	1	3	0	6	10	33	16	49
Texas	19	18	18	23	22	100	16	34	14	21	85	185	178	363
Coahuila	0	4	3	5	4	16	0	4	0	1	5	21	19	40
Nuevoleon	0	5	6	2	5	18	0	4	0	1	5	23	27	50
Tamaulipas	0	5	9	3	5	22	0	4	0	1	5	27	21	48

protecting the public lands, health, safety, and welfare, but not to build industrial parks or establish private industrial or commercial enterprises.

Much of the purchased land eventually was transferred to other federal agencies for administration as National Wildlife Refuges, National Parks, and other lands. Over 1.5 million ha in the Great Plains became National Grasslands in 1960. The lands are part of the National Forest System and are administered in compliance with numerous environmental statutes, including the Endangered Species Act, National Forest Management Act, National Environmental Policy Act, and others. There are many uses of National Grasslands, including livestock grazing and oil and gas leasing. However, no legislation, including Bankhead-Jones, establishes a preferred use. It is within the discretion of the U.S. Forest Service to determine within its planning process how uses should be managed and where uses should occur.

SPECIES OF CONCERN ON NATIONAL GRASSLANDS

Of the 1,031 species of concern in the Great Plains, 522 occur on one or more National Grasslands, including 19 amphibians, 42 reptiles, 95 birds, 37 fish, 55 mammals, 28 insects, 5 mollusks, and 241 plants. Twelve species are listed as endangered or threatened under the ESA and six are candidates for listing under ESA. Seventy-one species ranked by TNC as G1-G3 or T1-T3 are known or suspected to occur on one or more National Grasslands. These species include 5 reptiles, 8 birds, 5 fish, 8 mammals, 9 insects, 2 mollusks, and 34 plants.

The National Grasslands also harbor a large number of sensitive species included in the 522 species of concern noted above. The goals of the U.S. Forest Service sensitive species policy are to:

- maintain important species and habitat components in functional National Grassland ecosystems
- prioritize needed conservation work, with an emphasis on habitat
- ensure sensitive species are considered in land management decisions
- prevent a need for species listing under the ESA
- use these species and their habitats as a means to implement effective ecosystem management and provide for forest health
- implement the National Forest Management Act and agreements on conserving species tending toward federal listing as threatened or endangered.

National Grasslands are important for the conservation of species of concern in a region of North America dominated by privately owned land. The Grasslands can serve as examples of land management for species conservation for possible export to privately owned land.

Table 2. Distribution of the 188 Great Plains endemic species of concern as evidenced by their listing by one or more government agency or other scientific authority.

Province/State	Amphibians	Reptiles	Birds	Fish	Mammals	Total Vertebrates	Crustaceans	Insects	Arachnids	Mollusks	Total Invertebrate	Total Animals	Total Plants	Total Endemics
Alberta	0	0	3	0	1	4	0	0	0	0	0	4	0	4
Saskatchewan	0	0	3	0	1	4	0	0	0	0	0	4	1	5
Manitoba	0	0	2	0	1	3	0	0	0	0	0	3	0	3
Montana	0	0	3	0	1	4	0	0	0	0	0	4	2	6
North Dakota	0	0	3	0	1	4	0	0	0	1	1	5	3	8
South Dakota	0	0	3	0	1	4	0	0	0	1	1	5	4	9
Nebraska	0	0	1	0	1	2	0	0	0	0	0	2	3	5
Wyoming	0	0	2	0	1	3	0	0	0	1	1	4	5	9
Colorado	0	0	2	0	1	3	0	0	0	0	0	3	2	5
Minnesota	0	0	2	0	0	2	0	0	0	1	1	3	0	3
Iowa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missouri	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kansas	0	0	3	3	1	7	0	0	0	0	0	7	1	8
Oklahoma	0	0	3	4	1	8	1	0	0	1	2	10	6	16
New Mexico	0	0	3	4	1	8	1	0	0	2	3	11	2	13
Texas	18	7	5	11	2	43	16	15	14	6	51	94	90	184
Coahuila	0	2	1	1	0	4	0	0	0	0	0	4	8	12
Nuevoleon	1	2	1	0	0	4	0	0	0	0	0	4	17	21
Tamaulipas	1	4	1	0	0	6	0	0	0	0	0	6	17	23

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Table 3. Great Plains National Grasslands (gross ha including inholdings).

National Grassland	Size (ha)
Black Kettle, Oklahoma	12660
Buffalo Gap, South Dakota	241266
Caddo, Texas	7233
Cedar River, North Dakota	2718
Cimaron, Kansas	43776
Comanche, Colorado	176181
Fort Pierre, South Dakota	46618
Grand River, South Dakota	62718
Kiowa, New Mexico	55205
Little Missouri, North Dakota	416029
Lyndon B. Johnson, Texas	8219
McClellan Creek, Texas	586
Oglala, Nebraska	38234
Pawnee, Colorado	78127
Rita Blanca, Oklahoma and Texas	37631
Sheyenne, North Dakota	28436
Thunder Basin, Wyoming	266688
Total	1522325

PIPING PLOVER POPULATION CHANGES IN SASKATCHEWAN

Margaret Skeel

Nature Saskatchewan, 206 - 1860 Lorne St., Regina, Saskatchewan S4P 2L7

Karyn Scalise

Saskatchewan Environment and Resource Management, 3211 Albert St., Regina, SK S4S 5W6

Abstract: The piping plover population was censused across Saskatchewan in 1991, and again in 1996, as part of the International Piping Plover Breeding Census. The magnitude of numbers counted at several key locations differed substantially between the years, although the areas of concentration in both years had consistent use. The three most highly populated sites in 1996 had impressive increases over the 1991 counts: Big Quill Lake increased from 151 to 435 birds (the highest count in North America), Chaplin Lake from 113 to 205 birds, and Willow Bunch Lake from 31 to 124 birds. In contrast, Lake Diefenbaker, which had the highest count in North America in 1991, decreased from 276 to 75 birds. Wide fluctuations in numbers occurred at both small and large sites. The provincial population change was relatively small (an increase from 1172 to 1348 birds), suggesting that fluctuations at an individual site are more indicative of a movement from one basin to another, than of an overall population change.

The Saskatchewan population accounted for just over 20% of the total North American population in both years. Although the continental population increased 7.8%, numbers on the Prairies/Great Plains decreased 5.3%. Saskatchewan's increase of 15% may reflect an influx of plovers from elsewhere on the Prairies, in particular the Great Plains of the U.S. where a decrease in population was largely attributed to high water and flooding of much of the plover's river habitat.

INTRODUCTION

In 1991, and again in 1996, the piping plover *(Charadrius melodus)* was the focus of a census of suitable habitat across all known summer and winter ranges (Haig and Plissner 1992, Plissner and Haig 1997). Nine provinces and 28 states across Canada and the United States participated in a coordinated effort to attain a reliable estimate of the piping plover breeding population. Goals were to clarify status and distribution, and to monitor the success of recent recovery efforts. These censuses were the most extensive of any North American endangered species.

The piping plover, a small shorebird with a distinctive call and neck band, chooses very specific, and traditional, nesting habitat. Across the Great Plains, where the majority of the continental population resides, its nesting habitat is restricted to gravelly beaches, or sandy or alkali beaches with gravelly patches, along shores of rivers, saline or freshwater lakes and ponds. Just under half the continental population nests along the Atlantic coast on sandy beaches, and a remnant population nests in the Great Lakes region. Movement of piping plovers from year to year, in response to changing water regimes that define its transitional nesting habitat, precludes monitoring population changes at selected sites.

In 1985, the piping plover was designated "Endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) due to indications that it may have been in decline prior to 1980 (Bell 1978, Cairns and McLaren 1980), and evidence from later surveys of further decline (Harris et al. 1985). Surveys through the 1980s indicated a possible continuing decline, likely due to habitat deterioration caused by drought conditions on the Prairies, and increasing human disturbance. The piping plover was likely never abundant, and may be notably at risk to decline because of its choice of very specific and transitional habitat.

SELECTION AND CENSUSING OF SITES

Sites with records of piping plovers and sites with potential habitat were surveyed in 1991 and 1996. Sites varied in size from a few hectares to thousands of hectares. All wetlands south from the boreal forest in Saskatchewan were considered for the census (Skeel and Hjertaas 1993).

In 1991, although 486 sites were visited, a total of 294 sites with habitat or potential habitat were surveyed; the remaining were judged to have no potential habitat. In 1996, 276 sites were surveyed. Thirty-eight sites (excluding the Missouri Coteau area) judged in 1991 to have potential habitat or possible potential habitat were not surveyed because of no available habitat (or likely no habitat) due to higher water in 1996. The south shore of Lake Athabasca also was not surveyed in 1996, due to no plovers being found in 1991 and the inaccessibility of the area.

The same set of wetlands (excluding the Missouri Coteau area) was considered for the census in both years with the exception of three sites not visited in 1991 but identified since then as supporting plovers (22 plovers in 1996), and 16 sites not visited in 1991 but with marginal or unsuitable habitat in 1996 (0 plovers in 1996). In both years, sites with gravelly beaches in the Missouri Coteau, which supports hundreds of basins of varying size, were selected on the basis of a mid-May aerial survey (about 130 sites were identified and visited in both years). One small site that had habitat in 1996 was missed in the 1996 census (2 plovers in 1991).

Census procedures followed the guidelines used by all jurisdictions for the 1991 and 1996 international piping plover breeding censuses (Haig and Plissner 1992, Plissner and Haig 1997). In 1991, surveys were conducted between 26 May and 21 June; in 1996, the majority were conducted in the narrower window of 1-16 June in order to further minimize multiple counts due to migratory and post-breeding movements (Plissner and Haig 1997). For each site, the number of breeding pairs, single adults with a nest or young, and unpaired adults were noted. Number of adults recorded was defined as the number of territorial pairs (presumed mated) plus single adults with a nest or young. About 120 people participated in the census in Saskatchewan in each of the years.

POPULATION CHANGES

The piping plover population in Saskatchewan exhibited changes in both numbers and distribution between the 1991 and 1996 censuses. However, changes in distribution were most notable. The census results clearly demonstrated that concentrations of plovers can change dramatically; these changes are almost certainly in response to fluctuating water regimes and resulting changes in habitat conditions and availability. Movement of birds from one year to the next, rather than mortality or productivity, would have almost exclusively accounted for the large fluctuations that occurred at major sites.

Although pairs of piping plovers were distributed over 57 and 51 sites in 1991 and 1996, respectively, five large basins were home to a disproportionately large portion of the population in both years (Figure 1 and Figure 2). The five basins (Willowbunch Lake, Chaplin Lake, Big Quill Lake, Lake Diefenbaker, and Manitou

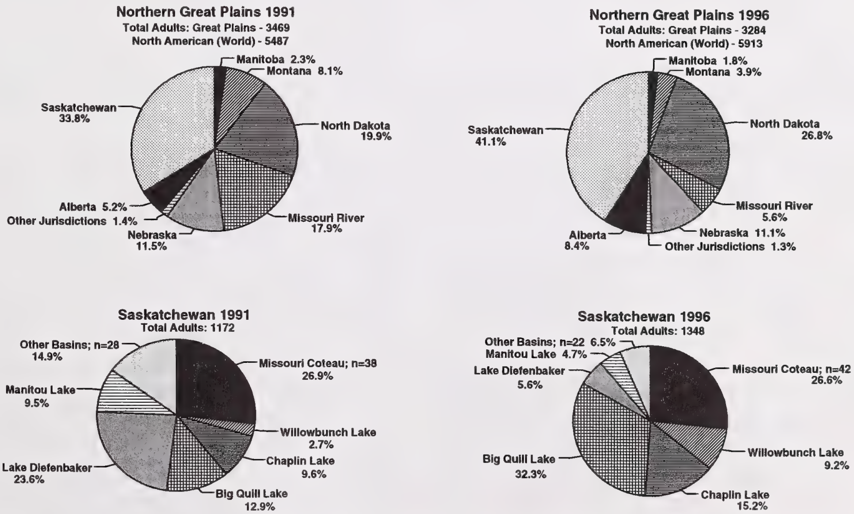

Figure 1. Changes in piping plover distribution on the Northern Great Plains and in Saskatchewan as reported in the 1991 and 1996 international breeding censuses. (From Plissner and Haig 1997; Skeel 1993; Skeel et al. 1997).

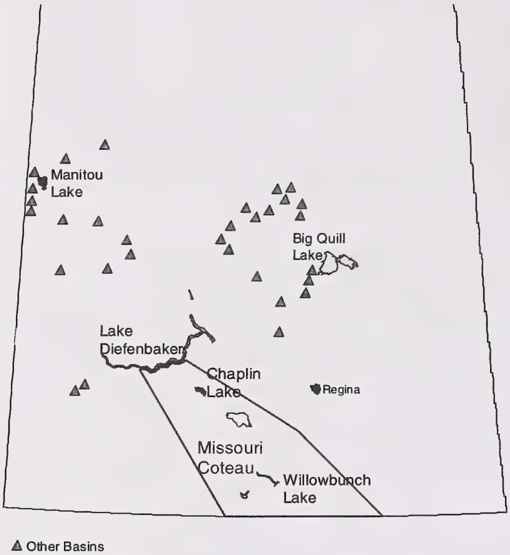

Figure 2. Locations of the five major basins, the Missouri Coteau, and other basins where Piping Plovers were reported in the 1991 and 1996 international Piping Plover breeding censuses. One location in each of the southeast and southwest where a single bird was reported in unusual habitat is omitted.

Lake) together supported 58% and 67% of the provincial population in 1991 and 1996, respectively. The geologically distinct Missouri Coteau (excluding Willowbunch and Chaplin lakes), with its numerous smaller basins, supported a further 27% in both 1991 and 1996, a significant portion of the population.

The magnitude of piping plover use varied at each of these five large basins between years (Table 1). The count of 276 birds at Lake Diefenbaker, the highest count in North America for 1991, dropped to only 75 birds in 1996. In contrast, the count of 151 birds at Big Quill lake in 1991 increased substantially to 435 birds, the highest count in North America for 1996. Dramatic changes also occurred at the remaining three large basins, Chaplin, Manitou and Willowbunch Lakes. Over 10 years of counts of varying completeness at Lake Diefenbaker, the population on the shores of the reservoir has varied from 61 (estimated) birds in 1990 to 360 (estimated) birds in 1984 (Skeel 1997). Counts at Big Quill Lake have varied from a low of 43 plovers in 1989 (Harris and Lamont 1989) to a high of over 440 birds in 1995 (W.C. Harris Pers. Comm.), representing a tenfold increase over a six-year period.

Number and densities of plovers at any one site are likely influenced by both the amount and quality of habitat available at the site, as well as availability over an extensive surrounding area. Movement dynamics likely involve many basins. When only the two large basins for which there are long-term counts, Lake Diefenbaker and Big Quill Lake, are compared there is no consistent relationship between counts (Skeel 1994, Skeel 1997, Skeel et al. 1997). For example, although Big Quill Lake had a low count of 43 birds in 1989 and a high count of over 440 birds in 1995, the population at Lake Diefenbaker was similar in both years at an estimated 120-135 birds. Movement between these two basins may be substantial in some years, but in other years surrounding basins may attract a greater portion of the plovers.

In any one year, piping plovers likely only use a portion of the basins that support plovers over the long-term. Although 101 basins supported plovers in 1991 and/or 1996 (excluding the 4 basins with plovers in one year but not surveyed the other year), only 68-70% of these basins had plovers in just one year. Only 35 basins (35%) had plover in both years (Skeel 1997). Although the number of sites judged to have habitat or the potential for habitat approached 300 in the 1991/1996 censuses, the number of sites judged to have suitable habitat in a given year was lower: 220 in 1991 and 167 in 1996. In 1996 78% of sites (69 of 88 sites) with "good" habitat supported plovers.

Change in basin use occurred primarily at smaller basins and/or at basins with smaller populations. Most basins with at least 10 plovers in 1991 or 1996 had plovers in the other year (17 of 23 basins). Wide fluctuations in numbers of plover from 1991 to 1996 occurred at both small and large basins.

The total population count of piping plovers in Saskatchewan increased 15% between 1991 and 1996 (from 1172 to 1348 birds). Although the Prairie Canada count increased by 17% (from 1437 to 1687 birds), total plover numbers over the Northern Great Plains of Canada and the U.S. decreased by 5% (from 3469 to 3284 birds; Plissner and Haig 1997). Saskatchewan's increase may be largely due to an influx of plovers from the U.S. Great Plains, where the decrease is largely attributed to high water and flooding of most nesting habitat along the Missouri River system. The decrease on the Northern Great Plains was overshadowed by the impressive increase of 30.4% in the Atlantic region. The North American (world) population increased by almost 8% (Plissner and Haig 1997).

Table 1. A comparison of selected counts of piping plovers as reported in the 1991 and 1996 international breeding censuses (from Plissner and Haig 1997, Skeel 1993, Skeel et al. 1997).

Name of Basin (# of basins)	1991 # of Birds or Pairs (# of Basins)		1996		CHANGE IN ADULTS	
	ADULTS	PAIRS	ADULTS	PAIRS	#	%
Missouri Coteau excluding Willowbunch and Chaplin Lakes	315 (38)	115 (27)	359(42)	120(29)	44	14
Willowbunch Lake (1)	31	16	124	57	93	300
Chaplin Lake (1)	113	51	205	74	92	81.4
Big Quill Lake (1)	151	54	435	196	284	188.1
Lake Diefenbaker (1)	276	122	75	28	-201	-72.8
Manitou Lake (1)	111	51	63	21	-48	-43.2
All Other Basins in Saskatchewan	175 (28)	72 (25)	87 (22)	38 (17)	-88	-50.3
Saskatchewan Total	1172 (71)	481 (57)	1348 (69)	534 (51)	176	15
Northern Great Plains Total	3469	1480	3284	1377	-5	-5.3
Prairie Canada	1437	589	1687	679	17	17.4
U.S. Great Plains	2032	891	1597	698	-21	-21.4
Great Lakes Total	40	17	48	21	8	20
Canada	0	0	1	0	1	
U.S.	40	17	47	21	7	17.5
Atlantic Total	1979	940	2581	1270	602	30.4
Canada	509	234	422	189	-86	-16.9
U.S.	1466	704	2153	1078	687	46.9
France (St. Pierre/ Miquelon)	4	2	6	3	2	50
NORTH AMERICAN (WORLD) TOTAL	**5487**	**2437**	**5913**	**2668**	**426**	**7.8**

A high proportion of the world population of piping plovers (21.4% in 1991 and 22.8% in 1996), and of the Northern Great Plains population (33.8% in 1991 and 41.0% in 1996) resides in Saskatchewan in the breeding season. Saskatchewan wetlands with piping plover habitat in some years, including both large and small basins, are important to the survival and recovery of this endangered species. Because the very specific habitat it selects is transitional in nature, the number of sites with suitable habitat in a given year represents only a portion of the sites that support, and thus are important to, piping plover over the long-term.

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ALBERTA AMPHIBIAN MONITORING AND SNAKE HIBERNACULUM PROGRAMS

Lisa Takats

Alberta Conservation Association, 7th Floor, O.S. Longman Building, 6909 - 116 Street, Edmonton, Alberta T6H 4P2

Steve Brechtel and Bruce Treichel

Alberta Environmental Protection, Natural Resources Service, Fish and Wildlife, 7th Floor, O.S. Longman Building, 6909-116 Street, Edmonton, Alberta T6H 4P2

Abstract: Amphibian and reptile populations have been declining throughout the world due to anthropogenic causes such as habitat loss, poor environmental conditions, and direct killing. The ecology of herpetile species in Alberta is poorly understood, and many of these species are sensitive and at risk of declining. A volunteer-based amphibian monitoring program was initiated in 1992, to collect information about the distribution of amphibians in Alberta. The objectives were to increase public participation in and awareness of amphibian research in Alberta and to work together with other amphibian projects being conducted in the province to collect additional information on amphibian ecology. Data were entered into the Biodiversity Species Observation Database (BSOD). The program presently has over 100 volunteers that send in information. There were 675 and 703 observations sent in by participants in 1996 and 1997, respectively, representing all ten of Alberta's amphibian species. One of the most important habitat components for snakes are the hibernacula (or dens). In 1996 a Snake Hibernaculum Inventory was initiated for the province of Alberta. The objective of this program was to document as many hibernaculum sites as possible in the province, and to enter them into the BSOD. This data can be provided to wildlife and land managers throughout the province to be used in wildlife and land management decisions. A total of 187 dens have been entered. Few den locations have been sent in from northern Alberta.

INTRODUCTION

Since 1989, there has been increasing concern over declines in herpetile populations. No single factor can explain the declines, although habitat destruction has been identified as a major problem (Heyer *et al*. 1994). Other issues include pesticides, acid rain, UV radiation, global warming, and direct killing.

The Status of Alberta Wildlife report (AEP 1996) outlines the management concerns and conservation efforts relative to amphibians in Alberta (Table 1). There are concerns over populations, habitats, and management of more than half of Alberta's amphibians. Over the last 35 years, the northern leopard frog has declined dramatically over much of its range in North America. The populations now appear extirpated over much of central Alberta and are greatly reduced in southern Alberta (Wagner 1997). The Canadian and Great Plains toads have declined and the spotted frog is reported absent from ponds where it had previously been found.

Snakes are considered one of the disliked groups of animals in the world (Oliver 1958). They are important to the environment as predators on rodents and insects, as well as food for other animals. All snakes in Alberta are Blue or Yellow listed (Table 1), indicating they may be at risk or are considered sensitive. The prairie rattlesnake has experienced declines in Saskatchewan and requires protection of key habitat elements (AEP 1996).

One of the most important habitat components for snakes are the hibernacula or dens. Snakes are cold-blooded, and therefore are sensitive to variations in temperature. They congregate in the fall in cracks or holes, crevices, and rocky outcrops to escape the cold of winter. In the spring the snakes will disperse from the hibernacula for the summer. If a hibernaculum is destroyed, entire populations of snakes could be eliminated.

Knowledge of which species occur in which area is fundamental to the understanding of amphibian ecology (Heyer *et al*. 1994). As well, long-term ecological studies

Table 1. The status of Alberta's amphibian and snake species (AEP 1996).

Species	Status
Northern Leopard Frog (*Rana pipiens*) Great Plains Toad (*Bufo cognatus*) Canadian Toad (*Bufo hemiophrys*)	Red List - populations of these species have declined, or are believed to have declined, to nonviable levels; require more detailed work on their status and management; species at risk
Spotted Frog (*Rana pretiosa*) Plains Spadefoot Toad (*Spea bombifrons*) Prairie Rattlesnake (*Crotalus viridis*) Western Hognose Snake (*Heterodon nasicus*)	Blue List - species that are particularly vulnerable because of non-cyclical declines in population or habitat, or reductions in provincial distribution
Long-toed Salamander (*Ambystoma macrodactylum*) Bull Snake (*Pituophis melanoleucus*)	Yellow B List - sensitive species which are naturally rare, have clumped breeding distributions, or are associated with habitats that are, or may be, deteriorating
Wandering Garter Snake (*Thamnophis elegans*) Plains Garter Snake (*Thamnophis radix*) Red-sided Garter Snake (*Thamnophis sirtalis*)	Yellow A List – sensitive species for which there has been concern expressed over long-term declines in numbers
Boreal Toad (*Bufo boreas*) Boreal Chorus Frog (*Pseudacris triseriata*) Tiger Salamander (*Ambystoma tigrinum*) Wood Frog (*Rana sylavatica*)	Green List - these species are not considered at risk; populations are stable and their key habitats are generally secure at present

help us understand general cycles and allow us to detect declines in populations.

On January 18, 1992, the Alberta volunteer amphibian monitoring project was initiated (Powell and Russell 1993). In the pilot years (1992-1994) 17 respondents sent in 265 individual amphibian reports on 10 species. All reports were from south of the city of Edmonton. The Alberta Amphibian Monitoring Program (AAMP) was developed through the Fish and Wildlife Division of the Natural Resources Service (NRS) in 1994 and 1995. In 1996, it was run as a pilot program. In 1997 the program ran with a full-time coordinator through the Alberta Conservation Association and NRS. The objectives of the project were to:

1) Collect information on the distribution of amphibian species in the province of Alberta.
2) Increase public awareness of and participation in amphibian research in Alberta.
3) Work together with other amphibian projects being conducted in the province to collect additional information on amphibian ecology.
4) Coordinate meetings and distribute information about the different amphibian research projects in Alberta.

In 1996 a Snake Hibernaculum Inventory was initiated for the province of Alberta through Alberta Environmental Protection, Fish and Wildlife. The objective of the program was to document as many hibernaculum sites as possible, and to enter them into the Biodiversity Species Observation Database (BSOD). This data can be provided to wildlife and land managers throughout the province for use in wildlife and land management decisions.

METHODS

Amphibian Monitoring

The amphibian monitoring program was advertised through natural history journals (Edmonton Naturalist, The Steward, The Willet), radio, letters to NRS field offices, and word of mouth, in early spring of 1996 and 1997. An instructional package (manual and tape) was sent out to all interested volunteers. Participants were encouraged to record their sightings on data sheets that were included in the back of the manual, and send them in to the Wildlife Management Division, Natural Resources Service, Edmonton. Once the data sheets were sent in to the office, they were entered into the BSOD. The total number and chronology of observations and number of individuals was determined for each species. The types of observations (behaviour-vocalizations, habitat, population structure) and the age of the individuals (adults, larvae/eggs, young of year) observed were also noted. A newsletter was sent out to all participants highlighting the results after each field season.

The coordinator also worked with various research projects throughout Alberta. This included helping with field work, coordinating meetings, and coordinating the exchange of information.

Snake Hibernacula

An overview sheet about the Snake Hibernacula project and data sheets were sent to all Natural Resource offices and Provincial Parks. Data sheets that were returned were entered into the BSOD. A Snake Information Manual was produced for wildlife officers and biologists to help answer some of the questions the public has about snakes. Historical data from previous snake hibernacula studies were entered into BSOD.

RESULTS

Amphibian Monitoring

A total of 85 and 101 volunteers supplied data to the monitoring program in 1996 and 1997 respectively (Figure 1). A total of 675 (1996) and 703 (1997) records were entered into BSOD (Table 2), representing all 10 species of amphibians in Alberta.

Some of the more keen volunteers recorded calls in the spring, made videos on frogs, and took pictures of the amphibians and the habitats in which they were found. Volunteers sent in sightings of other species besides amphibians. These included a great blue heron colony, and even a wild boar sighting.

The newsletter was named by Ed Hofman, one of the volunteers in the monitoring program. The first issue of "Croaks and Trills" came out in June 1997, and overviewed some of the interesting findings from 1996, as well as providing volunteers with extra reading material on amphibians in Alberta. A similar issue in January, 1998 overviewed the data from 1997.

The monitoring program helped with an Edmonton amphibian survey which was initiated by the Edmonton Natural History Club (Dean and Ostopowich 1997 a and b). Four species of amphibians were recorded in the 22 sites sampled: Canadian toad, boreal toad, boreal chorus frog, and wood frog. A total of 59 observations from this project were entered into the BSOD. The RANA project (Research on Amphibian Numbers in Alberta) was initiated by Brian Eaton of the Biological Sciences Department at the University of Alberta. The monitoring program worked along with the RANA project to set up three intensive monitoring sites in Alberta: Lesser Slave Lake, Meanook Biological Station near Athabasca, and Beaverhill Lake.

Frog deformity and disease was found in three cases during these studies. In 1996, a volunteer reported on wood frog deformities in the Fort McMurray region. "In a 90 minute period, we caught 50 frogs, mostly wood frogs, eight of which were deformed; one had only one eye, one had one hind leg that was not bendable, one had a front leg missing, and the others had only one hind leg." In 1997, a deformed wood frog was found at Moran Lake, near Edmonton. The specimen had legs,

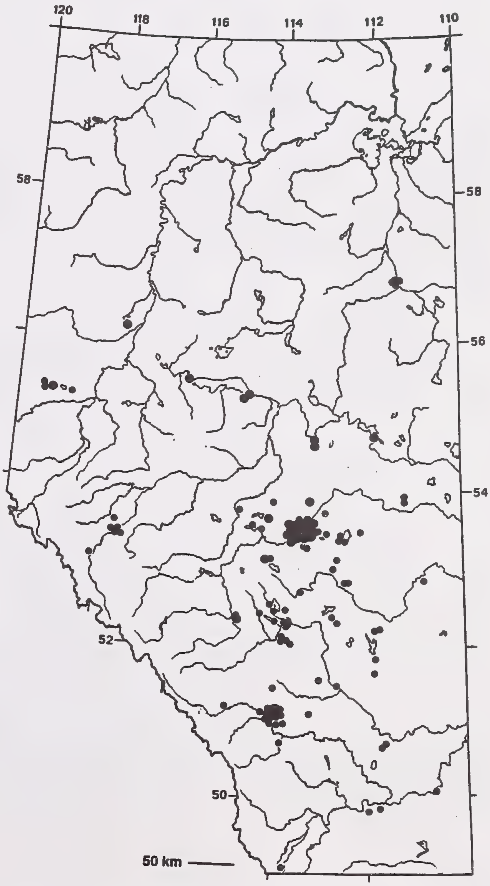

Figure 1. Distribution of participants in the amphibian monitoring program in 1996 and 1997

Table 2. Overview of amphibian data sent in by volunteer participants in the monitoring program.

Species of Amphibians	1996 Number of Observations	1996 Number of Individuals	1997 Number of Observations	1997 Number of Individuals
Tiger Salamander	25	152	35	291
Long-toed Salamander	4	5	3	170
Plains Spadefoot Toad	8	38	1	1
Boreal Toad	15	70	39	624
Great Plains Toad	6	24	0	0
Canada Toad	26	31	15	21
Boreal Chorus Frog	326	3 362	296	13 770
Wood Frog	248	897	296	7 288
Spotted Frog	6	6	8	117
Northern Leopard Frog	11	35	10	404
Total Records	675	4 620	703	22 686
Number of Participants	85		98	

but a large portion of the tail remained. The tail was thick and blunt. The mouth and body were still tadpole-like and the individual was lethargic and had poor mobility. The third case occurred in northwest Edmonton. High numbers of lethargic, bloated tadpoles were found. A tadpole was collected for examination, and was found to be infected with a bacteria equivalent to red leg disease in adult frogs (Dean and Ostopowich 1997 a and b).

Snake Hibernaculum

A total of 290 observations have been entered into the BSOD including all six provincial species of snakes (Table 3). Of these, only 187 dens have been entered. Few den locations have been sent in from northern Alberta

CONCLUSION

The loss of habitat, as well as the alarming decline of some populations of amphibians around the world, make it important for biologists, naturalists and amphibian enthusiasts to continue to collect information on the distribution and ecology of amphibian species (Corkran and Thoms 1996). Amphibians are susceptible to environmental change, and can thus serve as monitors of the health of our environment. Long-term studies are required in order to document the change in distribution of amphibians over time. Long-term studies can also detect population trends and natural cycles in populations over time (Brooks 1992). Some Alberta amphibian species such as boreal chorus frog and wood frog are in great abundance. Because of this, many people fail to see the declines in other less visible species (Roberts 1992).

There are many keen people that enjoy observing wildlife. The volunteer program provides these individuals an opportunity to participate in the collection of data about the natural environment. Increasing the public's awareness of the importance of amphibians in the ecosystem is the first step to managing them. Ultimately, the public can directly influence the quantity and quality of amphibian habitat.

Table 3. Number of snake observations, dens and individuals observed in suitable habitat and total individuals counted entered into the BSOD program.

Species	# of Observations	# of Dens	# Observed in Suitable Habitat	Total Individuals Counted
Red-sided Garter Snake	16	13	3	811
Wandering Garter Snake	14	11	3	875
Plains Garter Snake	13*	11	1	10 631
Bullsnake	53	53	-	6363
Hognose Snake	8	6	2	372
Prairie Rattlesnake	186	93	93	5359

* one road kill data point

FUTURE WORK

Two concurrent years of data have been collected in this study. To ensure long-term monitoring continues, these programs must continue to encourage public participation in herpetological surveys. Future work will include producing a poster on the amphibians and reptiles of Alberta. This poster will overview the importance of herpetiles to the environment, and will have photos and descriptions of the different species in Alberta.

The Amphibian Monitoring Program could be used successfully in elementary schools as part of their pond study. Ponds could be surveyed yearly as different classes go through the curriculum. Schools will be contacted throughout Alberta, to encourage participation. A teacher's guide to the Amphibian Monitoring Program will be created. There will also be an effort to look at the possibility of northern leopard frog reintroduction into sites where they existed previously.

Finally, there will be an effort to revisit historical snake hibernaculum sites to determine if they are still active.

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INTRODUCTION TO THE ALBERTA RAPTOR MONITORING PROGRAM

Lisa Takats

Beaverhill Bird Observatory, 7th Floor, O.S. Longman Building, 6909-116 Street, Edmonton, Alberta T6H 4P2

Abstract: A Raptor Monitoring Program was initiated in August 1997 to collect standardized, long-term, ecological information on raptors in Alberta. The objectives of this project are to: 1) collect information on raptor fall migration at Beaverhill Lake, 2) to set up a volunteer-based owl monitoring program (similar to the Breeding Bird Survey), 3) to collect morphological and location information on dead raptors turned in to Natural Resources Service offices, and 4) to work with raptor banders and the public to collect standardized information on cavity and stick nesting raptors in the province. Seventeen different raptor species were recorded during migration at Beaverhill Lake from August through October 1997. Northern harriers *(Circus cyaneus)*, red-tailed hawks *(Buteo jamaicensis)*, and short-eared owls *(Asio flammeus)* were the most common raptors recorded. Birds of prey were caught and banded throughout the fall. Nineteen stick nests have been documented and morphological information on 90 raptors (representing 18 species) has been col-

INTRODUCTION

The Alberta Raptor Monitoring Program was initiated in August 1997 to collect standardized, long-term, ecological information on raptors in Alberta. The objectives are to:

- Collect information on migrating and nesting raptors at Beaverhill Lake.
- Set up a volunteer-based owl monitoring program, similar to the Breeding Bird Survey but focussed on nocturnal owls.
- Collect morphological and location information on dead raptors that are turned in to Alberta Environmental Protection, Natural Resources Service.
- Work with raptor banders and the public to collect standardized information on cavity and stick nesting raptors in the province.

Raptors are an important group of birds to consider when managing our environments. The position of birds of prey high on the food chain makes them ideal indicators of environmental health (Oliphant 1994).

METHODS

Fall surveys were conducted at Beaverhill Lake (east of Edmonton). All observations of raptors were recorded from August through October. A variety of techniques were used to trap and band migrating raptors: drop-lid traps, drop-door traps, Bal Chatri traps, and mist nets with a decoy or recorded calls.

Volunteers were contacted to conduct owl call surveys in the spring of 1998. A standard survey protocol will be provided for the volunteers. Dead raptors that were turned in to the Alberta Natural Resources Service were sexed and aged (if possible), measured (wing chord, tail length, foot pad, tarsus, weight), and moult patterns of the wing and tail were recorded. A poster was created asking the public to report any stick nests and raptors they find on their property.

RESULTS

Seventeen species of raptors were recorded during fall migration surveys in 1997 (Table 1). Northern harriers, red-tailed hawks, and short-eared owls were the most common raptors recorded. Throughout the fall, sightings of short-eared owls and red-tailed hawks dropped, while great horned owls and bald eagles increased. Accipiters were sighted throughout the three months. Five species of raptors were caught and banded: sharp-shinned hawk, Cooper's hawk, northern goshawk, broad-winged hawk, red-tailed hawk, and great gray owl.

Ninety dead raptors, representing 18 species, have been processed to date (February 16) (Table 2). Only 50 of these raptors had location information associated with them. Four banded birds were turned in, none of

Table 1. Number of raptors seen at Beaverhill Lake, August through October, 1997.

Species	August	September	October	Total
Bald Eagle	0	4	18	22
Northern Harrier	61	73	55	189
Sharp-shinned Hawk	5	3	1	9
Cooper's Hawk	2	2	0	4
Northern Goshawk	2	3	3	8
Swainson's Hawk	14	8	2	24
Red-tailed Hawk	30	19	5	54
Broad-winged Hawk	0	3	0	3
Rough-legged Hawk	0	1	6	7
American Kestrel	0	0	2	2
Merlin	2	3	0	5
Peregrine Falcon	2	1	0	3
Gyrfalcon	0	0	1	1
Osprey	0	0	1	1
Great Horned Owl	7	13	5	25
Short-eared Owl	33	14	10	57
Northern Saw-whet Owl	0	2	0	2

which had been reported to the banding office. Over 63 % of the dead raptors were hatch-year birds. Great horned owls, short-eared owls, red-tailed and Swainson's hawks were the most common raptors turned in.

Eighteen stick nests have been located and will be visited in the spring to determine occupancy.

FUTURE WORK

The project is still in its beginning stages. Future work will include:

- conducting fall migration surveys again in 1998; standardized locations and times will be set up for volunteers and staff to record observations of raptors; trapping will continue
- educating the public on bird banding and the importance of recording information about where and when a bird of prey is found
- conducting volunteer owl call surveys along transects in March and April, 1998; (Takats 1998)
- transects that were surveyed for owls in previous years will be surveyed again
- continuing morphology work on dead raptors
- selecting two grids as study areas to collect information on nesting success, productivity and nesting habitat information

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Table 2. Sex and age of dead raptors turned in to the Natural Resources Service.

Species	Males (age)	Female (age)	Unknown (age)
Sharp-shinned Hawk	1 (1HY)	0	1 (1HY)
Northern Goshawk	1 (1HY)	0	0
Swainson's Hawk	3 (2HY,1SY)	5 (2AHY, 3HY)	2 (1HY,1ASY)
Red-tailed Hawk	2 (1HY, 1ASY)	9 (1AHY, 7HY, 1SY)	1 (AHY)
Broad-winged Hawk	2 (2HY)	0	0
Rough-legged Hawk	3 (1AHY, 2HY)	2 (1AHY, 1HY)	0
American Kestrel	1 (1HY)	0	0
Merlin	4 (2AHY, 2HY)	3 (3AHY)	1 (1HY)
Prairie Falcon	0	1 (1HY)	0
Peregrine Falcon	0	1 (1HY)	0
Barred Owl	0	1 (1HY)	0
Boreal Owl	1 (1HY)	0	1 (1HY)
Northern Saw-whet Owl	(1AHY, 1HY)	1 (1AHY)	3 (3U)
Northern Pygmy Owl	0	0	1 (1HY)
Great Horned Owl	5 (1AHY, 4HY)	5(1AHY,1HY,1SY,2U)	10 (9HY, 1U)
Long-eared Owl	0	2 (2HY)	1 (1SY)
Short-eared Owl	5 (2AHY, 3HY)	3 (1AHY, 2HY)	4 (4HY)
Snowy Owl	0	2 (1AHY, 1HY)	0

AHY=after hatch year, HY=hatch year, SY=second year, ASY=after second year, U=unknown

Observatory staff and executive. This work would not have been possible without the hard work and new ideas of my research assistant Christine Rice.

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DRYING OUT OF PRAIRIE SLOUGHS DUE TO CHANGES IN DRAINAGE BASIN LANDUSE

G. van der Kamp

National Hydrology Research Institute, Environment Canada, 11 Innovation Boulevard, Saskatoon, Saskatchewan, S7N 3H5

W. J. Stolte

Department of Civil Engineering, University of Saskatchewan, Saskatoon, Saskatchewan

R. G. Clark

Prairie and Northern Wildlife Center, Canadian Wildlife Service, Environment Canada, Saskatoon, Saskatchewan, S7N 0X4

Abstract: Water level data have been collected since 1968 for numerous small wetlands within a 385 hectare area in the northern prairie region of Canada. The uplands around the wetlands were under dryland cultivation in 1968. Between 1980 and 1983 about one-third of the area was converted to a permanent cover of brome grass and alfalfa with the purpose of providing improved bird nesting habitat. The remainder of the area continued in cultivation. The water level records show that wetlands within the grassed area dried out within a few years after conversion of their drainage basins to permanent cover, whereas wetlands in the neighbouring cultivated area retained water as before. These results provide a clear example of the importance of land use to the water balance of prairie wetlands.

INTRODUCTION

The northern glaciated plains of North America have many small wetlands in more-or-less isolated drainage basins. These wetlands, commonly referred to as 'potholes" or "sloughs", constitute valuable wildlife habitat and have important functions in the surface and subsurface hydrology of the region. The water levels in the wetlands are subject to large seasonal and inter-annual fluctuations, reflecting the semi-arid continental climate. During droughts many of the wetlands dry out entirely, with serious repercussions for wildlife. Thus the possible deleterious or beneficial effects of climate change or of changing land-use are of concern for wildlife and for water resource management.

Numerous studies dealing with the water balance of prairie wetlands have been carried out (e.g. Hayashi et al. 1998, Labaugh et al. 1996, Meyboom, 1966, Millar 1971, Shjeflo 1972, Sloan 1972, Winter 1989, Winter and Rosenberry 1995, Woo and Rowsell 1993). Springtime runoff from snowmelt on frozen soils is the main source of water in the wetlands, followed by summer precipitation on the wetlands and occasional summer-time runoff due to extreme precipitation events. Typically, about 25 to 50 per cent of the snow falling on the drainage basin enters the wetland as runoff. Water loss from the wetlands is almost entirely by evaporation and transpiration from the zone of open water and by evapotranspiration from the surrounding moist margins via seepage from the open water. Recharge or discharge of groundwater to or from regional groundwater aquifers is generally minor relative to the other factors that control the water balance of the wetlands (van der Kamp and Hayashi 1998).

Potential evapotranspiration considerably exceeds precipitation in the prairie region; hence, little or no surface runoff will reach the wetlands if the snowmelt or rain is absorbed by infiltration into the soils. Springtime runoff occurs only because the soils are still frozen and have limited infiltration capacity at that time of year (Gray et al. 1985). Any changes in land-use that might change the amount of spring runoff would have important implications for the water balance of the prairie wetlands. The land-cover in the prairie region has changed from native grasses to dryland cultivation and continues to change with evolving cultivation practices, which generally involve less tillage of the soils and increasing amounts of stubble material left on the land. These changing land-use practices may have important effects on runoff and the water balance of wetlands. Covich et al. (1997), after reviewing the potential effects of climate change on prairie wetlands, recommend that the effects of land-use be studied by means of paired drainage basins.

This paper describes a thirty-year record of wetland water levels which demonstrates the importance of land use for the water balance of small prairie potholes. Land use changed from dryland cultivation to permanent grass cover in part of a wetland complex, and within a few years wetlands in the grassed area dried out.

STUDY AREA

The St. Denis National Wildlife Area (NWA), located in central Saskatchewan (106° 06'W, 52° 02'N), comprises about 385 hectares and contains numerous wetlands (Figure 1). The elevation of the NWA ranges between 545 and 560 m above sea level. The topography of the area is described as moderately rolling knob-and-kettle moraine with slopes varying from 10 to 15% (Miller et al. 1985).

In 1980 and 1983 parts of the NWA were converted from dryland cultivation to a permanent cover of brome grass and alfalfa. Figure 1 indicates the approximate extent of the areas of brome grass, cultivated land, and untilled land including "willow rings" around the wetlands. (By 1997, brome grass was the predominant vegetation in the converted area, with little alfalfa in evidence). The purpose of the conversion to permanent grass was to provide improved bird nesting habitat. However, this change of land use had unforeseen but profound effects on the water balance of wetlands and thus constituted an inadvertent experiment on the hydrological effects of changes in land use.

The hydrogeology and soils of the NWA are described by Miller et al. (1985) and by Hayashi et al. (1998). The area is underlain by about 100 m of glacial deposits, consisting mostly of clay-rich glacial tills with low permeability. Sands are encountered sporadically within these deposits, but the only sand layer that may have continuity across the site is a 1 to 2 m thick layer of sand at a depth of about 30 m. The soils are described

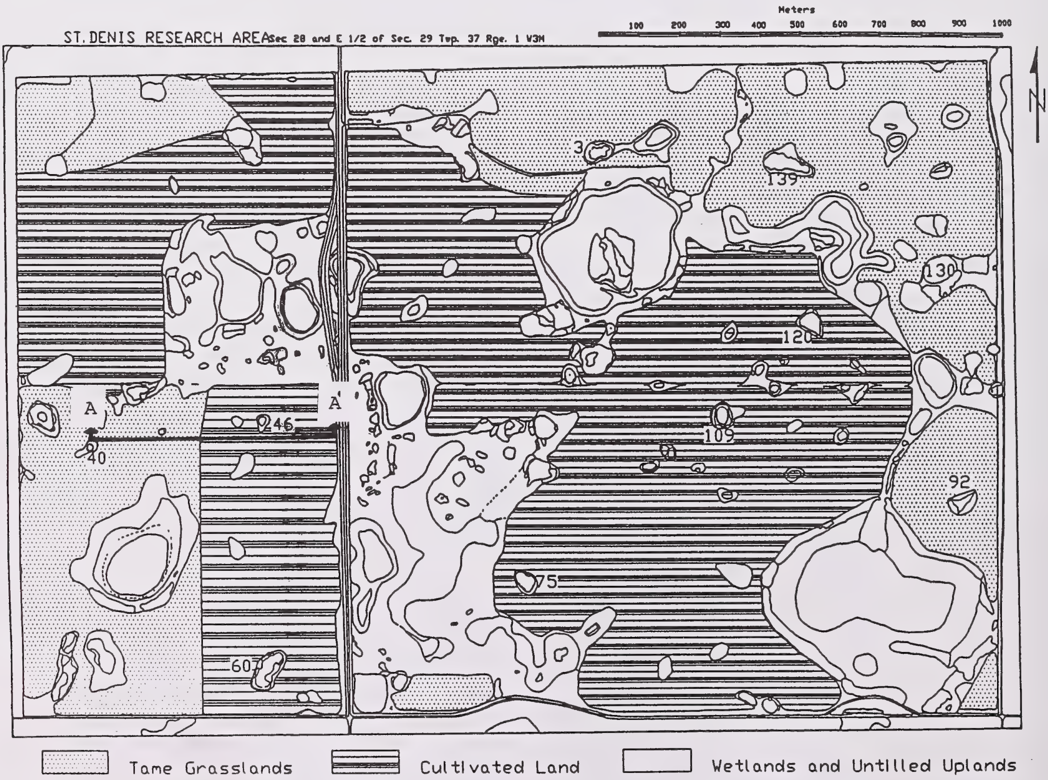

Figure 1. Plan of St. Denis National Wildlife Area.

as dominantly orthic dark brown developed from moderately to fine-textured unsorted glacial till (Miller et al. 1985). Such clay-rich soils and underlying glacial deposits typify much of the northern glaciated plains.

The annual mean air temperature at Saskatoon Airport, about 50 km west of the NWA, is 2º C, with monthly means of -19º C in January and 18º C in July (Atmospheric Environment Service 1997). The area generally becomes covered by snow in November and the snowmelt runoff occurs in several episodes in late March and April. The 90-year mean annual precipitation in Saskatoon is 360 mm, of which 84 mm occurs in winter mostly as snow (Atmospheric Environment Service 1997). The annual evaporation from large lakes in this area is 690-710 mm (Morton 1983), based on the data from Last Mountain Lake, located 100 km south-east of the study site.

The hydrology of one of the wetlands in the NWA, #109, has been studied intensively between 1993 and 1997 (Hayashi et al. 1998). This study showed that 109 is a recharging wetland which contributes about 2 mm per annum, averaged over the drainage basin area, to the regional groundwater flow system. The hydrogeology of wetlands 109 and 120 is also described by Miller et al. (1985) as part of a study of the relation between hydrology and soil formation.

METHODS

At the NWA water levels in ponds have been monitored by point measurements since 1968. Details of how water-level measurements were obtained are given by Millar et al. (1997). Steel stakes were driven into the ground at various locations, always including one stake at the deepest part of the wetland. Water levels were measured near accessible stakes and converted to depth of water near the central stake. Due to frost action, the stakes were subject to considerable heaving (Shjeflo 1972) and therefore the measured water levels were always verified with reference to several stakes and with reference to the actual water depth. The data are reported as water levels with reference to the deepest part of the ponds, i.e. the water levels correspond to the maximum depths of the ponds at the time of measurement . The water level measurements are generally accurate and reproducible to within 5 cm. For some of the wetlands, water level data are not available for 1994 and 1995.

Water level data for the period 1968-1997 were compiled for ten small isolated wetlands in the NWA (Millar et al. 1998). Five of the wetlands (#'s 46, 60, 75, 109 and 120) have drainage basins that remained in cultivation and five (#'s 3, 40, 92, 130, and 139) have drainage basins that were converted to permanent brome grass. These 10 wetlands are identified by number in Figure 1. The areas of each of the wetlands lie in the range of 0.1 to 0.3 hectares. The drainage basins of the wetlands are not well defined because there are numerous small upland depressions which do not support wetland vegetation and which may overflow and contribute water to lower-lying wetlands only in years of high spring runoff.. The approximate extent of the drainage basins is suggested by earlier studies (Shjeflo 1972, Hayashi 1998) which indicate that on average each prairie wetland occupies about 10 per cent of its drainage basin.

Each of the ten wetlands is surrounded by a partial or complete ring of trees and the associated grasses and bushes. These "willow rings" were in existence in 1968 and have generally been stable since then, with the exception of wetland 109 where the willow ring developed starting in 1968 (Millar et al. 1998).

RESULTS AND DISCUSSION

Figure 2 (a+b) shows the water level records for five wetlands with cropped catchments and five with grassed catchments. The water levels of five wetlands with cropped catchments throughout the period from 1968 to 1997 are shown in Figure 2a, while the water levels of the wetlands with grassed catchments after 1985 are in Figure 2b.

The effects of changing the drainage basin land-use from cultivation to permanent brome-grass/alfalfa cover are clearly evidenced by the water level records shown in Figure 2. During the period 1968-1980, prior to the change of land use, the water level fluctuations in the wetlands all show similar regimes. For example, water levels were very low in all the wetlands in 1968, 1977 and 1978 while high water levels were recorded for all the wetlands in 1975 and 1979. This pattern continued during the period 1981 to 1986 when the grass cover was becoming established. From 1987 onward, wetlands in the grassed area became much drier than the unchanged wetlands. In fact they have remained almost totally dry since then, discounting the inflow in the spring of 1997 into wetlands 40 and 139 from the cultivated farm lands outside the NWA.

Some of the wetlands receive overflow from outside their normal drainage basins in some years, or they overflow into lower wetlands. In the spring of 1997,

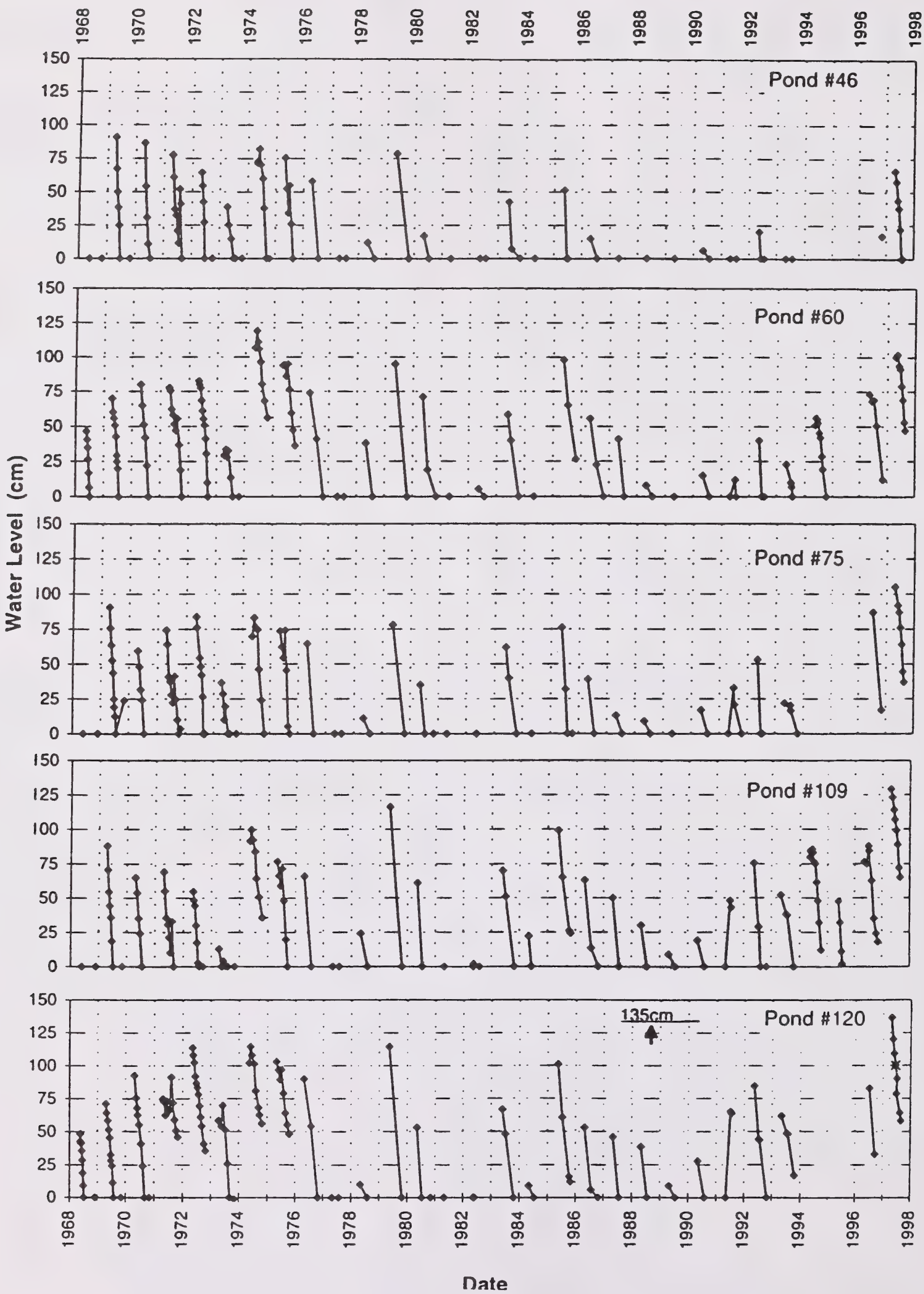

Figure 2a. Water level data 1968-1997. Wetlands in cultivated area. Overflow levels are indicated where they are less than 150 cm.

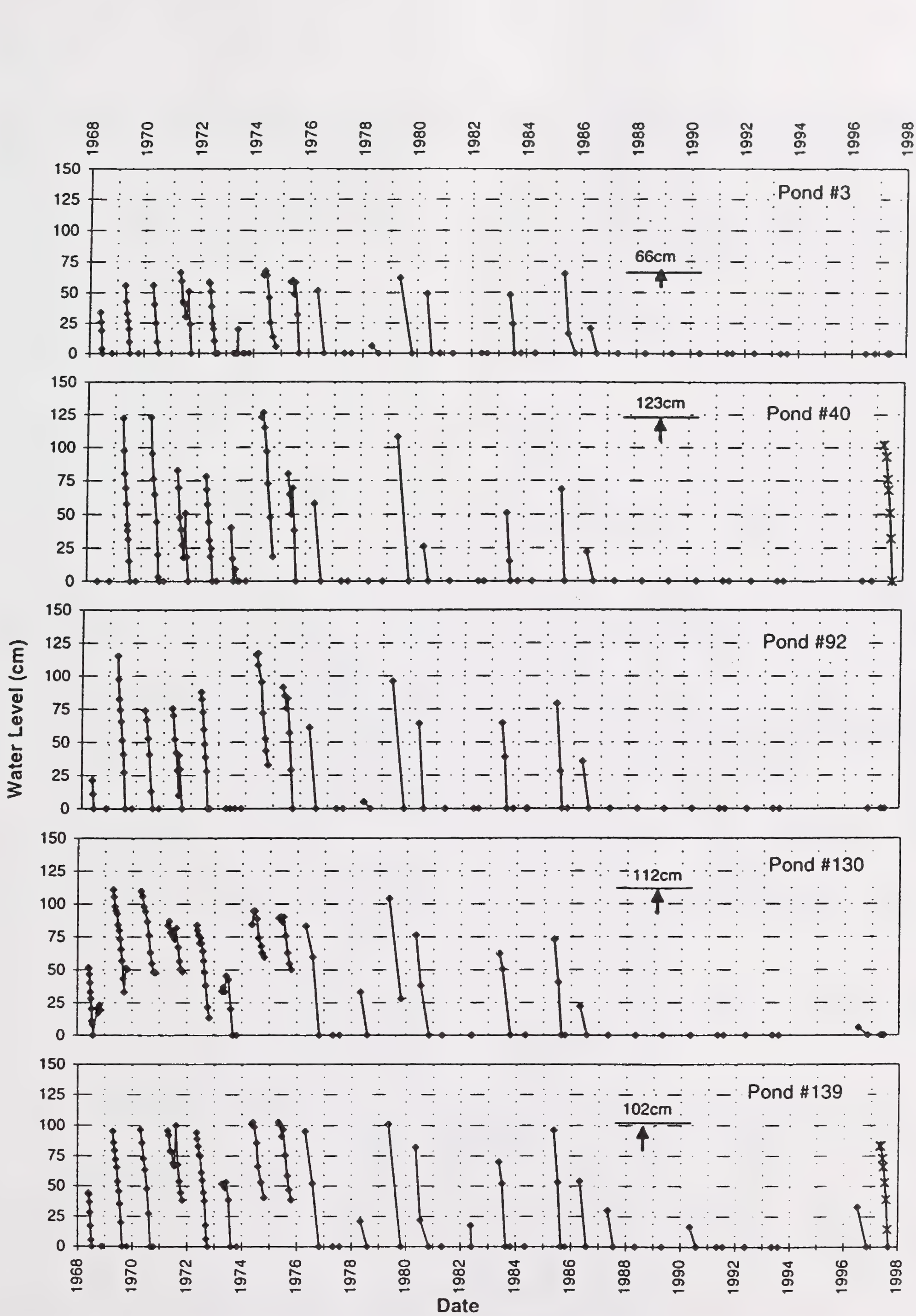

Figure 2b. Water level data 1968-1997.Wetlands in area that was changed from cultivation to permanent brome grass between 1980 and 1983. Overflow levels are indicated where they are less than 150 cm.

snowmelt runoff in the NWA was probably the heaviest for the period of record, due in part to a heavy fall of snow in April. Wetland 40 in the grassed area received overflow runoff from the larger wetland to the northwest, which in turn received runoff from cultivated farmland further west. Wetland 139, also in the grassed area, received overflow runoff from the cultivated farmland to the north. In 1997, wetland 120 overflowed into the larger wetland to the north, apparently for the first time since 1968. Wetlands 2, 3, 40, 130 and 139, all in the grassed area, overflowed several times between 1968 and 1985.

Informal observation and preliminary snow surveys, carried out in March and April of 1997, showed that in the cultivated land there were large snow drifts in depressions and willow rings. In the grassed area, on the other hand, the snow cover was uniformly distributed, with little evidence of snow drifting. This is illustrated in Figure 3, which shows the results one of the preliminary snow surveys carried out on the 22nd of March 1997 along a west-east line starting at slough #40 within a grassed area and carrying on into a fallowed field, just south of slough #46 (Line A-A in Figure 1). There was little evidence of ephemeral sheet-water ponds in the grassed area during the snowmelt season, whereas there were numerous such ponds in the cultivated area.

IMPLICATIONS

Considering the complexity of the processes that are involved in generating runoff from snowmelt and rainfall, the change in hydrology of the wetlands is remarkably clear. The reasons for this change of hydrology are not yet established. It may be that brome grass, with its tall stiff stems, is particularly effective in reducing soil moisture, trapping snow on drainage basin slopes and inducing infiltration of snowmelt moisture.

Existence of a permanent grass cover does not necessarily lead to greatly reduced runoff. Labaugh et al. (1996) describe a wetland complex in the Cottonwood Lake area of North Dakota where the upland cover consists of ungrazed native grass (T.C. Winter, Pers. Comm.), but where there appears to be ample spring and summer runoff into the wetlands. Thus it would appear that factors other than the permanence of the vegetative cover must be taken into account.

The very marked hydrological effect of the change in land use described in this paper suggests that other changes of land use may have important hydrological effects. At present there is a trend in prairie farming practice toward conservation tillage, generally involving less tillage and more stubble retention. Such practices may mimic to some extent the introduction of permanent grass. Thus it is conceivable that conservation tillage may lead to lowered water levels in prairie wetlands even as it acts to increase soil moisture availability on the uplands.

The marked effects of land use changes documented in this paper also indicate that possible effects of climate change on the water balance of prairie wetlands are likely

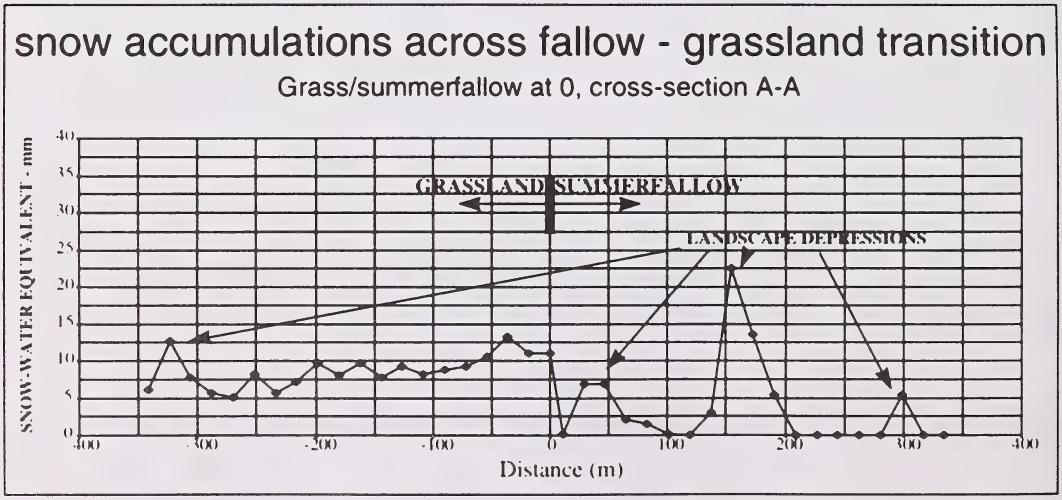

Figure 3. Results of a snow survey taken on March 22, 1997, along a west-east line starting at pond # 40.

to be masked by the effects of changing agricultural practices. Clearly land management would be the tool of choice for counteracting the deleterious effects, if any, of climate change and for achieving a balance in the competition for water between agriculture and wetlands.

CONCLUSIONS

The long-term water level data presented in this paper show conclusively that when the drainage basins of small prairie wetlands were converted from cultivation to tame brome grass, the wetlands dried out and remained dry, even in years of heavy precipitation.

The study demonstrates that the hydrology of prairie wetlands is highly sensitive to land-use in the surrounding drainage basin. It is likely that introduction of permanent ground covers with effective snow-trapping properties will lead to lowering of wetland water levels.

ACKNOWLEDGMENTS

J.B. Millar provided invaluable contributions to this study, based on his long-term familiarity with the St. Denis site. P.J. Kiss assisted with compilation of the data and preparation of graphics. R. Schmidt provided useful observations of snow and runoff conditions on the site.

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INFLUENCE OF PRAIRIE DOG COLONIES AND CLIMATIC VARIATION ON BIRD COMMUNITIES IN KANSAS SHORTGRASS PRAIRIE

Stephen L. Winter and Jack F. Cully, Jr.

Kansas Coop. Fish & Wildl. Res. Unit, Kansas State University, Manhattan, Kansas 66506

Jeffrey S. Pontius

Department of Statistics, Kansas State University, Manhattan, Kansas 66506

Abstract: Species richness and relative abundance of species in bird communities were quantified on black-tailed prairie dog (*Cynomys ludovicianus*) colonies and non-colonized areas in the shortgrass region of southwest Kansas in 1996 and 1997. Field sampling in 1996 occurred after twelve months of below average precipitation, and we found no difference in total relative abundance or relative abundance of any species when prairie dog colonies were compared to non-colonized sites. Field sampling in 1997 occurred after 10 months of above average precipitation. In 1997 relative abundance of horned larks (*Eremophila alpestris*) was highest on prairie dog colonies, while total relative abundance and relative abundance of lark buntings (*Calamospiza melanocorys*) and grasshopper sparrows (*Ammodramus savannarum*) was highest on non-colonized sites. Burrowing owls (*Athene cunicularia*) were only detected on prairie dog colonies during both years of the study. Bird species richness on prairie dog colonies was not higher than on non-colonized sites during either year of the study. Our results contrast with the results of research conducted in other areas of the Great Plains which have found higher species richness and higher relative abundance of all birds on prairie dog colonies than on non-colonized sites. Our results suggest that in the semi-arid shortgrass region prairie dog colonies are not "oases" of bird diversity to the same extent that they may be in mixed-grass regions, and that climatic variation may both nullify and magnify any habitat differences that birds perceive between prairie dog colonies and non-colonized areas.

INFLUENCE OF PRAIRIE DOGS ON VEGETATION IN KANSAS SHORTGRASS PRAIRIE

Stephen L. Winter and Jack F. Cully, Jr.
Kansas Coop. Fish & Wildl. Res. Unit, Kansas State University, Manhattan, KS 66506

Jeffrey S. Pontius
Department of Statistics, Kansas State University, Manhattan, KS 66506

Abstract: We quantified plant species richness, frequency, percent cover and percent bare ground on black-tailed prairie dog colonies and non-colonized areas in southwest Kansas in 1996 and 1997. In 1996 field sampling occurred after 12 months of below-average precipitation, while field sampling in 1997 occurred after 10 months of above-average precipitation. In 1996 prairie dog colonies were characterized by lower percentages of grass cover and higher percentages of forb cover than non-colonized sites, but there was no difference in percent bare ground. In 1997 percent grass cover, forb cover and bare ground was similar for prairie dog colonies and non-colonized areas. A preliminary analysis indicates that plant species richness of prairie dog colonies was similar to that of non-colonized areas. In 1996 four perennial grasses, two perennial forbs and one annual forb differed in frequency among the treatments. In 1997 seven perennial grasses, seven perennial forbs, six annual or biennial forbs and one annual grass differed in frequency among the treatments.

INTRODUCTION

A substantial portion of the research on black-tailed prairie dog *(Cynomys ludovicianus)* ecosystems has been conducted in a limited area of the Great Plains, namely the mixed-grass region of South Dakota (see Whicker and Detling 1988 for review), but the dynamics of prairie dog ecosystems in that bioregion may not be duplicated in areas with different climatic conditions and characteristic plant communities. There is a need to clarify how the dynamics of prairie dog ecosystems differ between bioregions. Further clarification is also needed on whether prairie dog ecosystems are a unique and essential community type for many species, or if prairie dog ecosystems are merely locations where biological components of grasslands assume altered levels of distribution and abundance. Here we report preliminary results of vegetation research that was conducted as part of a larger two-year study of the bird, plant, herpetile and insect diversity present at black-tailed prairie dog colonies and non-colonized areas in a shortgrass region of southwest Kansas. The species specific results we present here are limited to those species for which a significant difference was found among treatments. Identification of all specimens collected during sampling for this study has not been completed, and analysis of results will continue into the future. However, we believe these preliminary results are useful in understanding the influence of prairie dogs on vegetation in the shortgrass region of southwest Kansas.

STUDY SITE AND METHODS

Study sites were located at Cimarron National Grassland and adjacent private land in Morton County, southwest Kansas, USA. Cimarron National Grassland comprises more than 43,700 ha of land administered by the U.S. Forest Service. The majority of this land is characterized by a cover of perennial grasses and is utilized for cattle grazing. Most of the surrounding private land is utilized for the production of annual crops, though some areas remain in perennial grass cover and are used for cattle grazing. Study sites occupied areas with silty loam soils and slopes of 0 to 6%. Precipitation recorded at the Elkhart weather station in Morton County during the twelve months preceding the 1996 sampling period was 10.4 cm below the long-term mean of 44.9 cm. Precipitation during the twelve months preceding the 1997 sampling period was 23.21 cm above the long-term mean.

In 1996 eight of the largest prairie dog colonies and five non-colonized sites were selected for study. The criterion used to select non-colonized sites was a visual determination that buffalograss (*Buchloe dactyloides*), blue grama *(Bouteloua gracilis)*, or both species were the dominant grass at the non-colonized sites.

Additionally, we randomly selected eight non-colonized sites from a list of potential sites that had soil types and slopes that were identical to the soil types and slopes that characterized the prairie dog colonies. We had no prior knowledge of what type of vegetation was growing at the random sites when they were selected. Study sites in 1996 varied in size from 32.4 ha to 64.8 ha. In 1997 thirteen prairie dog colonies, six shortgrass sites and the eight random sites were sampled. Study sites in 1997 varied in size from 6 to 80 ha.

Sampling was conducted using a 0.10 m^2 rectangular plot nested inside a 10.0 m^2 circular plot. Percent cover of live grass, live forbs, and of each species, and percent bare ground were estimated within the 0.10 m^2 plot. Frequency of occurrence of each species was quantified within both the 0.10 m^2 and the 10.0 m^2 plot. In 1996 sampling occurred at 40 randomly located points at each study site. In 1997 the number of randomly located points sampled at each site was proportional to the area of the site, thus only 20 points were sampled at some of the smaller prairie dog colonies while up to 60 points were sampled at some of the larger random sites. Species richness values for 1996 were calculated by determining the total number of species encountered at each study replicate. Species richness values for 1997 were calculated by determining the number of species encountered on a ten-plot basis at each study replicate. Plots within each study replicate were assigned to each group of ten on a random basis.

One-way analysis of variance and the Kruskal-Wallace non-parametric test using Statistical Analysis System procedure (SAS v. 6.11 1996), and a Tukey-type non-parametric multiple comparison (Zar 1996) were used to test for significant differences between the means of treatments. Analyses of data were conducted on species richness, percent cover of live grass and live forbs, percent bare ground, frequency of occurrence in 10.0 m^2 plots and frequency of occurrence in 0.10 m^2 plots. We accepted type I error at $\alpha = 0.05$ for analysis of variance and Kruskal-Wallace tests. A value of $Q > 2.39$ generated by the Tukey-type test indicated significant differences.

RESULTS

Table 1 lists mean ± SE percent cover of live grass, live forbs, percent bare ground, species richness, and the frequency of species in which significant differences were detected between means of treatments at prairie dog colonies, non-colonized shortgrass sites and non-colonized random sites in 1996. In 1996 percent cover of live grass was significantly higher on non-colonized random sites than on prairie dog colonies and percent cover of live forbs was significantly higher on prairie dog colonies than on both the non-colonized shortgrass sites and non-colonized random sites. There was no significant difference in percent bare ground or species richness between prairie dog colonies, non-colonized shortgrass sites and non-colonized random sites. The perennial grass *Aristida purpurea* was more frequently

Table 1. Mean ± SE percent cover of live grass, live forbs, percent bare ground, species richness and frequency of species in which significant differences were detected between means of treatments at prairie dog colonies, non-colonized shortgrass sites and non-colonized random sites in 1996.

	Prairie Dog Colonies (n = 8)	Shortgrass Sites (n =5)	Random Sites (n = 8)	P - value
	mean ± SE	mean ± SE	mean ± SE	
Percent Cover Live Grass	30.71 ± 1.79^a	32.84 ± 1.23^a	44.29 ± 2.19^b	0
Percent Cover Live Forbs	18.31 ± 2.96^a	7.63 ± 1.47^b	7.11 ± 1.73^b	0.004
Percent Bare Ground	30.11 ± 3.17^a	28.25 1.95^a	32.1 3.08^a	0.703
Species Richness	43.63 ± 2.16^a	43.4 ± 2.27^a	46.63 ± 2.44^a	0.555
Frequency in 10.0 m^2 Plots				
Ambrosia confertifolia	4.69 ± 3.00^{ab}	10.66 ± 5.24^a	1.25 ± 0.94^b	0.034
Astragalus lotiflorus	1.56 ± 1.05^a	0	9.38 ± 4.38^b	0.019
Bouteloua curtipendula	0.31 ± 0.31^a	4.00 ± 2.32^a	61.88 ± 13.71^b	0.002
Buchloe dactyloides	68.13 ± 6.96^{ab}	87.36 ± 5.17^b	38.44 ± 14.48^a	0.048
Euphorbia glyptosperma	84.06 ± 8.00^a	92.48 ± 5.18^a	50.00 ± 11.88^b	0.015
Frequency in 0.10 m^2 Plots				
Aristida purpurea	54.38 ± 8.95^a	16.08 ± 4.00^b	27.81 ± 7.70^b	0.012
Bouteloua curtipendula	0.31 ± 0.31^a	1.00 ± 0.61^a	45.31 ± 11.92^b	0.002
Bouteloua gracilis	53.75 ± 11.87^a	87.48 ± 4.8^b	40.00 ± 8.14^a	0.016

encountered on prairie dog colonies than on non-colonized shortgrass and non-colonized random sites, and the annual forb *Euphorbia glyptosperma* was more frequently encountered on prairie dog colonies than on non-colonized shortgrass sites. The perennial grass *Bouteloua curtipendula* and the perennial forb *Astragalus lotiflorus* were more frequently encountered on non-colonized random sites than on prairie dog colonies, and the perennial grass *Bouteloua gracilis* was more frequently encountered on non-colonized shortgrass sites than on prairie dog colonies. The perennial grasses *Aristida purpurea*, *Bouteloua gracilis* and *Buchloe dactyloides*, the perennial forb *Ambrosia confertifolia*, and the annual forb *Euphorbia glyptosperma* were more frequently encountered on non-colonized shortgrass sites than on non-colonized random sites. The perennial grass *Bouteloua curtipendula* was more frequently encountered on non-colonized random sites than on non-colonized shortgrass sites.

Table 2 lists the mean ± SE percent cover of live grass, live forbs, percent bare ground, species richness and the frequency of species in which significant differences were detected between means of treatments at prairie dog colonies, non-colonized shortgrass sites and non-colonized random sites in 1997. In 1997 there were no significant differences between prairie dog colonies, non-colonized shortgrass sites and non-colonized random sites in the percent cover of live grass, live forbs, percent bare ground and species richness. The perennial grasses *Aristida purpurea*, *Buchloe dactyloides* and *Schedonnardus paniculatus*, and the annual forbs *Euphorbia strictospora*, *Kochia scoparia*, *Plantago patagonica* and *Salsola* sp. were more frequently encountered on prairie dog colonies than on non-colonized random sites. The perennial grass *Schedonnardus paniculatus* and the perennial forb *Sphaeralcea coccinea* were more frequently encountered on prairie dog colonies than on non-colonized shortgrass sites. The perennial grasses *Andropogon saccharoides*, *Bouteloua curtipendula* and *Sporobolus cryptandrus*, the perennial forbs *Asclepias latifolia*, *Convolvulus equitans*, *Gaura coccinea* and *Psoralea tenuiflora*, the biennial forb *Tragopogon dubius*, and the annual forb *Astragalus nuttallianus* were more frequently encountered on the non-colonized random sites than on the prairie dog colonies. The perennial grass *Bouteloua gracilis*, the perennial forb *Oenothera triloba*, the biennial forb *Tragopogon dubius*, and the annual grass *Hordeum pusillum* were more frequently encountered on the non-colonized shortgrass sites than on the prairie dog colonies. The perennial forbs *Asclepias latifolia*, *Convolvulus equitans*, *Gaura coccinea*, *Mirabilis linearis* and *Psoralea tenuiflora* were more frequently encountered on the non-colonized random sites than on the non-colonized shortgrass sites. The perennial grasses *Bouteloua gracilis* and *Buchloe dactyloides*, the perennial forb *Oenothera triloba*, and the annual grass *Hordeum pusillum* were more frequently encountered on the non-colonized shortgrass sites than on the non-colonized random sites.

DISCUSSION

Research on prairie dog ecosystems in South Dakota mixed-grass prairie (Archer et al. 1987, Cid et al. 1991, Coppock et al. 1983) has demonstrated that colonization and habitation by prairie dogs in that region results in a displacement of many perennial grasses, a replacement of mid-height grasses by short-height grasses and an increase in abundance of annual forbs. Archer et al. (1987) and Coppock et al. (1983) both reported higher plant species richness on prairie dog colonies than non-colonized sites, but Cid et al. (1991) reported no difference in plant species richness. Archer et al. (1987) also reported an increase in bare ground after colonization by prairie dogs. Research conducted in the shortgrass region of eastern Colorado found higher species richness on prairie dog colonies than non-colonized areas, while individual species responses to prairie dog colonization that were reported were a reduction of *Bouteloua gracilis*, an increase of *Buchloe dactyloides* and no effect on *Sphaeralcea coccinea* (Bonham and Lerwick 1976).

Our preliminary results support many of the findings of previous studies. In 1997 four of the five species of annual forbs reported here had their highest frequencies on prairie dog colonies. Presumably these annual forbs are responding to increased opportunities for germination and growth that are provided by the soil mounding and spreading that results from the burrowing activities of prairie dogs. Like previous studies, our results indicate several perennial mid-height grasses (*Andropogon saccharoides*, *Bouteloua curtipendula* and *Sporobolus cryptandrus*) that presumably have a low tolerance for frequent clipping and were less frequently encountered on prairie dog colonies than non-colonized sites. Additionally, five of six perennial forbs had their highest frequencies on non-colonized sites when compared to prairie dog colonies. We also suspect that the tendency of these perennial forbs to be more frequently encountered on non-colonized sites demonstrates a low tolerance to frequent repeated clipping by prairie dogs. The two perennial grass species (*Aristida purpurea* in 1996 and 1997 and *Buchloe dactyloides* in 1997) that were more frequently encountered on prairie dog

Table 2. Mean ± SE percent cover of live grass, live forbs, percent bare ground, species richness and frequency of species in which significant differences were detected between means of treatments at prairie dog colonies, non-colonized shortgrass sites and non-colonized random sites in 1997.

	Prairie Dog Colonies (n = 13)	Shortgrass Sites (n = 6)	Random Sites (n = 8)	P - value
	mean ± SE	mean ± SE	mean ± SE	
Percent Cover Live Grass	51.79 ± 3.10[a]	60.01 ± 2.90[a]	51.41 ± 0.68[a]	0.132
Percent Cover Live Forbs	10.56 ± 2.57[a]	6.37 ± 1.4[a]	10.01 ± 1.96[a]	0.329
Percent Bare Ground	32.68 ± 2.61[a]	27.06 ± 4.54[a]	33.44 ± 0.86[a]	0.098
Species Richness	28.45 ± 1.98[a]	27.68 ± 1.20[a]	30.18 ± 1.56[a]	0.698
Frequency in 10.0 m^2 Plots				
Andropogon saccharoides	4.87 ± 3.60[a]	16.3 ± 6.99[ab]	20.03 ± 7.37[b]	0.015
Aristida purpurea	86.99 ± 3.70[a]	72.08 ± 6.99[ab]	56.08 ± 8.86[b]	0.012
Asclepias latifolia	0.88 ± 0.88[a]	0.97 ± 0.62[a]	2.90 ± 21.16[b]	0.017
Bouteloua curtipendula	3.68 ± 2.66[a]	17.60 ± 10.05[ab]	57.55 ± 12.94[b]	0.001
Buchloe dactyloides	65.38 ± 8.23[a]	73.82 6.67[a]	32.1 11.82[b]	0.021
Convolvulus equitans	0.38 ± 0.38[a]	0.53 ± 0.53[a]	3.63 ± 1.37[b]	0.005
Euphorbia strictospora	8.96 ± 2.67[a]	2.60 ± 1.64[ab]	0.20 ± 0.20[b]	0.007
Gaura coccinea	11.08 ± 3.06[a]	6.83 ± 1.91[a]	25.48 ± 4.69[b]	0.006
Hordeum pusillum	14.26 ± 4.30[a]	45.48 ± 11.07[b]	6.79 ± 2.63[a]	0.017
Kochia scoparia	23.25 ± 5.28[a]	9.02 ± 4.27[ab]	2.80 ± 0.75[b]	0.004
Mirabilis linearis	4.71 ± 1.44[ab]	0.55 ± 0.55[b]	6.44 ± 2.12[a]	0.049
Oenothera triloba	3.08 ± 2.30[a]	5.72 ± 1.45[b]	1.26 ± 0.90[a]	0.014
Plantago patagonica	19.12 ± 4.64[a]	20.95 ± 11.01[ab]	3.05 ± 1.25[b]	0.048
Psoralea tenuiflora	11.92 ± 4.38[a]	18.35 ± 8.32[a]	43.81 ± 11.37[b]	0.015
Salsola sp.	10.89 ± 2.57[a]	1.45 ± 1.10[ab]	0.64 ± 0.45[b]	0.015
Schedonnardus paniculatus	66.19 ± 5.66[a]	25.73 ± 6.33[b]	22.48 ± 6.24[b]	0
Sporobolus cryptandrus	10.35 ± 4.40[a]	36.73 ± 10.94[b]	38.11 ± 8.55[b]	0.01
Tragopogon dubius	0.22 ± 0.22[a]	10.28 ± 4.32[b]	7.30 ± 2.73[b]	0.001
Frequency in 0.10 m^2 Plots				
Astragalus nuttallianus	0.22 ± 0.22[a]	0.55 ± 0.55[ab]	2.09 ± 0.82[b]	0.02
Bouteloua gracilis	37.81 ± 9.26[a]	81.00 ± 7.07[b]	41.88 ± 7.68[a]	0.012
Psoralea tenuiflora	0.66 ± 0.66[a]	1.42 ± 1.07[ab]	5.56 ± 3.78[b]	0.046
Sphaeralcea coccinea	35.12 ± 4.63[a]	14.28 ± 2.87[b]	23.94 ± 4.41[ab]	0.017

colonies when compared to non-colonized sites possess morphological adaptations that enable them to avoid or tolerate herbivory: *Aristida purpurea* is protected by an abundance of long, sharp-tipped awns, while *Buchloe dactyloides* is a low growing, stoloniferous species that is highly tolerant of grazing. We encountered *Bouteloua gracilis* more frequently on non-colonized shortgrass sites than on prairie dog colonies. This and our results for the perennial grass *Buchloe dactyloides* are similar to the results obtained by Bonham and Lerwick (1976). Bonham and Lerwick (1976) also reported that even though the perennial forb *Sphaeralcea coccinea* was regularly consumed by prairie dogs at their study site, it was apparently tolerant of this herbivory and did not differ in abundance between colonized and non-colonized sites. Further evidence for a tolerance to herbivory by *Sphaeralcea coccinea* is suggested by the higher frequency of this species in our study in 1997 on prairie dog colonies than on non-colonized shortgrass sites. In contrast to the findings of Archer et al. (1987) in South Dakota and Bonham and Lerwick (1976) in Colorado, we did not find a difference in species richness when prairie dog colonies were compared to non-colonized sites. We also did not find the increased amount of bare ground on prairie dog colonies that Archer et al. (1987) reported.

Our preliminary results and the results of studies in other areas of the Great Plains indicate that prairie dogs influence vegetation in ways that are common among different regions. Our results also demonstrate that the influence of prairie dogs on vegetation can differ between different regions of the Great Plains. We intend to further examine our data in an attempt to identify the influence, or lack of influence, of prairie dogs on species diversity, community similarity, percent cover of individual species, and frequency of occurrence of groups of species such as perennial grasses.

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GAME FARM DEVELOPMENT IN SASKATCHEWAN: SHOULD WE BE CONCERNED?

Stuart Slattery

Department of Biology, University of Saskatchewan, 115 Perimeter Road, Saskatoon, Saskatchewan S7N 0X4

Jantina Portman

Site 509, Box 28, Rural Route #5, Saskatoon, Saskatchewan S7K 3J8

Abstract: Game farming is an alternative agricultural practice that promises to be lucrative for farmers during difficult times. Currently, game farmers make most money from sales of antler and breeding stock, although Saskatchewan Agriculture and Food (SAF) expects this industry to evolve into a meat market. Native game animals are better at converting feed to meat, require less shelter, and do better on marginal land than do domestic livestock species. This marginal land is often the only habitat available to wildlife in our highly fragmented agricultural landscape. Herein lies one of the many conflicts between game farming and wildlife conservation: if agriculturally unproductive land is concerted to ecologically overstocked game farm pasture, where will wild animals go? Other concerns include risk of introducing disease into wild populations, creating a legal market for illegal wildlife parts of live animals, reducing public respect for wildlife, genetic contamination of wild stocks, and privatization of wildlife.

We currently have more than 264 game farms in this province. SAF and Saskatchewan Environment and Resource Management (SERM) anticipate exponential growth of this industry and have developed proposed policy to regulate game farming. Although missing a literature review that could allow readers to assess sustainability of proposed policy, the document addresses many (but not all) concerns. However, it also makes several disconcerting proposals, e.g. allowing game farming on Crown, cultivated lease land because "These lands have limited value as wildlife habitat." SAF and SERM are also evaluating public opinion using a questionnaire seemingly biased towards supporting game farming. The overall tone of these documents raises concern for the welfare and biodiversity of Saskatchewan ecosystems.

"If the goal is to maintain wild populations both now and in the future, the formulation of enabling legislation for game farming should proceed with far more caution than has been in evidence to date" (Twiss et al. 1996).

Game farming is an alternative agricultural practice that promises to be lucrative for farmers during difficult financial times (Saskatchewan Agriculture and Food Web-page). Currently, most game farming revenue comes from sales of antler and breeding stock, although Saskatchewan Agriculture and Food (SAF) expects this industry to further develop foreign and domestic markets for meat and capture a portion of the beef industry (Anonymous 1998, SAF Web-page). Native game animals are more efficient at converting feed to meat, require less shelter, and do better on marginal land than do domestic livestock species.

Unfortunately, this marginal land is often the only land available to wildlife in our highly fragmented agricultural landscape. Herein lies one of the many conflicts between game farming and wildlife conservation: if agriculturally unproductive lands are converted to game farm pasture as has been done worldwide (Scotland-Blaxter et al. 1974, Meuron 1975, Germany-Koch 1976, New Zealand-Yerex 1979, England-Wagner 1984, Asia-Drew et al. 1989, Hungary-Somogyvari 1993, Ireland-Connolly 1995), where will wild animals go? The list of conservation concerns surrounding game farming is large and has biological, philosophical and political aspects. Biologically, game farming threatens wildlife through loss of habitat due to fencing and overstocking, reduction in biodiversity, risk of introducing disease into wild populations, and genetic contamination of wild stocks (Anonymous 1991, Kahn 1993, Dratch 1993, Miller and Thorne 1993, Twiss et al. 1996). On philosophical grounds, turning native animals into, essentially, another species of privately-owned cow may trivialize wild animals and reduce public interest in wildlife and support of wildlife-oriented programs (Giest 1985, Posewitz 1993, Samuel and Demarais 1993). Finally, creation of a legal market for illegal wildlife parts or live animals, diversion of public funds from other wildlife programs, and regulation of wildlife issues by an agricultural branch of government (Kahn 1993, Wheaton et al. 1993) could dismantle some basic tenets of wildlife conservation (Geist 1988) and result in nonsustainable wild populations (Anonymous 1991, Twiss et al. 1996). Many of these conservation concerns are based on real incidents which occurred worldwide (reviewed in Anonymous 1991, Kahn 1993, Dratch 1993, Miller and Thorne 1993, Wheaton et al. 1993, Twiss et al. 1996). Legislators must learn from these past problems created by game farming and base proposed policies and regulations on sound ecological/conservation principles.

We currently have more than 264 game farms in Saskatchewan (only includes elk, moose, white-tail deer, mule deer and caribou farms and not exotic species; Anonymous 1998). SAF and Saskatchewan Environment and Resource Management (SERM) anticipate an industry growth rate of 15-20% per annum (Anonymous 1998) and have drafted proposed policies to regulate game farming in the stakeholders document, "Proposed Provincial Policy for Game Farm Development in Saskatchewan." We urge everyone to critically examine this document (available on the Internet at http://www.agr.gov.sk.ca/saf/live/sthcnsdc .htm). Although the document identifies many relevant concerns, several proposals are distressing. One such proposed policy would permit game farming on cultivated Crown lease land because "These lands have limited value as wildlife habitat", while another would allow farmers to live-trap animals attempting to enter game farm pens. Trapped animals would either be slaughtered (which is implied to be the best option) or released after disease testing (Anonymous 1998). Finally SAF and SERM are evaluating public opinion using what appears to be a biased questionnaire, one that could be construed as designed to transfer some powers of wildlife regulation from SERM to SAF, that is from a wildlife to an agricultural branch of government. Overall, the tone of these documents and the short, 1-2 month consultation period loosely ending March 9 suggest environmental short-sightedness (*sensu* Wilson 1992) and lack of concern for public opinion and for the welfare of Saskatchewan ecosystems.

Twiss et al. (1996) warned Canadian policy makers and legislators not to ignore public opinion or ecosystem health if viable wildlife populations are to exist. Farming of native wildlife is illegal in British Columbia, New Brunswick, Newfoundland, Nova Scotia, Prince Edward Island, Wyoming and Oregon (V. Geist Pers. Comm., Twiss et al. 1996). Despite proposed socio-economic benefits of game farming, residents of these jurisdictions favored the existence of wildlife in perpetuity.

When dealing with agricultural issues, one road block conservationists may face is that industry representatives either ignore or fail to understand that wildlife and wild places have intrinsic value and that healthy ecosystems provide many environmental benefits, such as water purification, sulfate reduction, carbon dioxide fixation, fertilization, and oxygen production (Purves et al. 1992). Many arguments are consequently simplified to economics. In addition to the biological, philosophical, and political concerns outlined above, the game farming issue has serious economic complications for both rural communities and the general public (Anonymous 1991, Twiss et al. 1996). For instance, during 1991, Saskatchewan residents spent about $173 million dollars on both consumptive and non-consumptive wildlife-related activities, and an additional $130 million dollars on recreational fishing (Filion et al. 1994). These dollar values do not include rural economic benefits from out-of-province visitors but nonetheless clearly demonstrate that wildlife and habitat are important to Saskatchewan residents. Compared to income from wildlife-related activities, only $3 million was earned by Saskatchewan farmers from the sale of velvet and venison in 1996 (Anonymous 1998). Income from sales of breeding stock was not available and may only represent a short-term, non-sustainable benefit as the industry grows and the demand for breeding animals declines (Anonymous 1991, Twiss et al. 1996, SAF Web-page). Thus, even from an economic standpoint, we question why our provincial government is willing to risk the health of Saskatchewan ecosystems for the economic benefit of a few individuals. In addition, there are regulatory, enforcement, and compensation costs (Twiss et al. 1996) which may or may not be funded by the industry, particularly at the current game farm license fee of $100 per year (SAF Web-page). For instance, a 1991 epidemic of bovine tuberculosis (TB) in Alberta resulted in the slaughter of about 2,400 game farm elk (Miller and Thorne 1993, Twiss et al. 1996). About $15 million in public funds were used to compensate game farmers, with an additional cost of $100 million being borne by Agriculture Canada (Pybus 1994 in Twiss et al. 1996). This TB epidemic was attributed to game farm elk imported from Montana (Anonymous 1992, Miller and Thorne 1993). Also, in a survey of 50

US and Canadian wildlife agencies (with a 90% response rate), Wheaton et al. (1993) determined that sportsman's dollars or public funds have largely subsidized game farming because current farming license and fee revenue generally has not paid for regulation of the industry. Given a predicted average compound growth rate of 24% per annum on game farm investments (SAF Web-page), if game farming is to develop in Saskatchewan, then the public should not subsidize any aspect of this industry.

Subsidies and conservation issues should be just part of public concern over game farming. We should also be concerned with the efficacy of government regulation, underscored by two recent events in the prairie provinces. In February 1998, a third cow in Manitoba tested positive for bovine TB, which resulted in a scare for Manitoba and eastern Saskatchewan farmers (Canadian Press 1998, Robertson 1998). This disease, which could seriously threaten export of Canadian beef, still exists despite rigorous testing by provincial and federal agencies. Other diseases transmitted between cattle and game animals which could also threaten Saskatchewan's beef industry include haemorrhagic disease, blue tongue, and possibly chronic wasting disease (Dulac et al. 1988, Jessup et al. 1990, Duckworth 1998). Saskatchewan game farm policies and regulations must be based on proven disease testing protocol.

In addition, Manitoba recently demonstrated the difficulty with regulating wildlife capture issues. In late 1995, the Manitoba government announced intentions to allow commercial elk ranching in the province (Friesen 1998). During the next two winters, the province live trapped wild elk for breeding stock. Although this trapping was supposed to be tightly controlled by the government, unregistered elk started appearing. Rather than punish criminal game farmers for clear violation of game laws, the government declared a two-week amnesty period so that all illegally held elk could be registered. Eighty-eight animals came in as a result (Freisen 1998). Given this lack of integrity among some game farmers, who will obtain financial benefit from these animals, the government basically legitimized wildlife law infraction and trivialized wildlife.

These captured wild animals have now become livestock and are being sold out of province, despite the presence of *Parelaphostrongylus tenuis* in Manitoba. *P. tenuis* is a nematode parasite that causes nervous disorder and paralysis in several species of ungulates (Anderson 1972). Manitoba elk have been purchased by at least one Saskatchewan farmer (Pers. Comm., name kept private). These elk underwent quarantine in Manitoba and are currently under quarantine in Saskatchewan. Although whitetail deer are the typical hosts for *P. tenuis*, studies have shown that elk can also carry low level infections (Samuel et al. 1992) and thus importation of these Manitoba animals could pose a high risk to Saskatchewan wildlife. In some species of ungulates, importation tests may be inadvertently fooled by normal antiparasite treatments; for example, Ivermectin can temporarily stop shedding of larvae without eliminating infections (Kocan 1985). Some importation protocols prohibit anthelminthic treatment within 30 days of testing (Canadian Cooperative Wildlife Health Centre 1998). Are parasite testing protocols sensitive enough to prevent false negatives and keep Western Canada *P. tenuis* free? Our literature review suggests not. Of note is that the majority of literature on the population effects of *P. tenius* have focused on moose (reviewed in Schmitz and Nudds 1994) because this species is the most threatened ungulate where *P. tenuis* exists naturally. However, this parasite also causes neurological disease or death in caribou, sheep, goats, llamas, fallow deer, and mule deer (Tyler et al. 1980, review in Canadian Cooperative Wildlife Health Centre 1998). If game farming allows *P. tenuis* to jump the current ecological barrier preventing a westward spread (review in Canadian Cooperative Wildlife Health Centre 1998), the unknown risk to wild mule deer populations may be high, considering the large overlap in range and habitat use between whitetails and mule deer in Saskatchewan.

Policy and regulations based mainly on economics and hearsay will fail ecosystems. Instead, we must learn from the biological literature and errors of other jurisdictions. However, the onus to demonstrate sound environmental policy before further developing game farming in Saskatchewan falls squarely on the industry and ministries promoting game farming. Post-hoc policies to clean-up foreseeable problems are no longer acceptable. Principles in the Saskatchewan Prairie Conservation Action Plan (in which SERM and SAF are members) and the Canadian Biodiversity Strategy should further guide development of game farm policies and regulations (Anonymous 1995, PCAP Committee 1998). These documents were developed through cooperation by conservation, agricultural and governmental partners and recognize that sustainable agriculture can exist with and promote healthy ecosystems, but only if legislation occurs with an ecological perspective. Without such an approach, the long-term existence of our ecosystems will be jeopardized (Anonymous 1995, PCAP Committee 1998) and we risk the French experience where game farms are developing from meat production into agro-tourism spots for wildlife viewing (Brelurut et al. 1995).

SAF and SERM state that the Saskatchewan game farm industry should develop "in harmony with the management of sustainable wildlife populations and their public uses" (Anonymous 1998). However, the political process currently being used to promote game farming in Saskatchewan appears to be economically oriented and conservation disoriented. The complete absence of literature review and lack of philosophical consideration in the proposed policies (Anonymous 1998) reflect negligence for wildlife and disregard for the majority of people in this province. We want SAF and SERM to base policies on sound biological principles and existing conservation goals, fairly assess public opinion and allow a second consultation period for the public to review revised policies before submission to Cabinet.

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