The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 129, Number 1

January–March 2015

The Ottawa Field-Naturalists' Club

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COVER: A Grizzly Bear (*Ursus arctos*) eating seeds from a Whitebark Pine (*Pinus albicaulis* Engelmann) cone in a 8–hectare refuge near Golden, British Columbia. See Hamer amd Pengelly, pages 8–14 in this issue. Photo by Kicking Horse Resort.

THE CANADIAN
FIELD-NATURALIST

Volume 129

2015

Volume 131
The Ottawa Field-Naturalists' Club Transactions

Promoting the study and conservation
of northern biodiversity since 1880

THE OTTAWA FIELD-NATURALISTS' CLUB

OTTAWA CANADA

The Canadian Field-Naturalist

Volume 129, Number 1 January–March 2015

Experimental Evidence of Spatial Memory and Home Range Affinity in White-tailed Deer (*Odocoileus virginianus*)

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Nelson, Michael E. 2015. Experimental evidence of spatial memory and home range affinity in White-tailed Deer (*Odocoileus virginianus*). Canadian Field-Naturalist 129(1): 1–7.

The role of spatial memory in the movement of animals through landscapes remains elusive. To examine spatial memory and home range affinity of White-tailed Deer (*Odocoileus virginianus*) in northeastern Minnesota during 1995–2007, I translocated 17 adult does with known home ranges to unfamiliar sites and radio-tracked them after their release. Twelve does wearing transmitting radio-collars returned to their home ranges. Death and collar expiration precluded determination of whether the remaining five does would have returned to home ranges. Three of five does wearing global positioning system collars traveled throughout hundreds of square kilometres, circling, backtracking, and returning to release sites, while two others exhibited directional movement for tens of kilometres. Four does that survived to parturition stopped traveling and moved at hourly rates similar to those of control does during the first three weeks of the typical fawn-rearing period, but continued traveling later. Their aberrant extensive travel before and after interruption by parturition suggests that they recognized they were in unfamiliar areas, demonstrating both their capacity and propensity to search for and occupy the familiar space of their individual home ranges. Their successful return to home ranges provided experimental evidence of spatial memory and further elucidated its pervasive role in White-tailed Deer spatial ecology.

Key Words: experimental translocation; home range; movements; *Odocoileus virginianus*; spatial affinity; spatial memory; White-tailed Deer

Introduction

The role of spatial memory in how animals move through landscapes remains elusive and its quantification challenging (Moorcroft 2012; Spencer 2012; Fagan *et al.* 2013). Memory effects in the spatial ecology of animals were postulated in the earliest observations of the movements of individual animals and were eventually confirmed with the development of radio-tracking technology (M]oorcroft 2012). With parallel advances in cognitive sciences and statistical analyses of animal movements, the influence of spatial memory is increasingly being recognized and incorporated into mathematical models of animal movement (Gautestad and Mysterud 2005; Borger *et al.* 2008; Gautestad 2011; Moorcroft 2012; Spencer 2012; Gautestad *et al.* 2013).

Because spatial memory is an internal cognitive process, movements based on memory may be directed toward space beyond an animal's current field of perception (Gautestad and Mysterud 2005; Moorcroft 2012; Fagan *et al.* 2013). Thus, to distinguish memory-based movements from movements elicited by the immediate external environment requires experimental manipulation (Moorcroft 2012). However, the spatial memory that animals possess before experimentation begins is unknown to researchers. Fagen *et al.* (2013) suggest one solution to this problem is tracking the spatial dynamics of juveniles throughout ontogeny to obtain complete movement histories before experimentation. They further suggest translocating these animals to novel environments, which may help identify movements influenced by previous spatial memories.

The movements of adult female White-tailed Deer (*Odocoileus virginianus*) and their fawns in northeastern Minnesota indicated that spatial memories developed by fawns following their mothers was a primary influence on their adult home-range locations, seasonal migrations, and landscape distribution (Nelson and Mech 1981, 1987, 1999, 2006; Nelson 1994, 1998). Further evidence of spatial memory was inferred from a pilot study in which adult females and fawns were translocated to unfamiliar areas (Nelson 1994). Some deer returned to their home ranges and resumed their previous movement patterns, while others did not return, but mimicked their pre-translocation movements near their release sites.

Traditional movements and home-range affinity not only suggest the capacity for spatial memory, but also imply a fitness advantage of the propensity to occupy familiar space. To collect experimental evidence of this capacity and propensity, I delineated the home ranges of adult does for at least a year before translocating them outside their home ranges. I then examined their movements relative to their home ranges and to the movements of does not translocated. If spatial memory was a major factor responsible for home range affinity, then translocated does would be predicted to return to their home ranges and not remain at their release sites or other sites they encountered that supported resident deer. A corollary of this prediction is that translocated does would employ different modes of movement than those of control does not translocated.

Study Area

I conducted this study in the Superior National Forest in northeastern Minnesota (48°N, 91°W). The topography was flat, and the area was dominated by lakes and mixed coniferous–deciduous forests (Heinselman 1996). Average monthly minimum temperatures ranged from 2°C to 18°C from May to October and −18°C to 7°C from November to April (Heinselman 1996). Snow cover generally occurred from November through April with weekly depths averaging 31–64 cm during February and March and 0–30 cm during April (Nelson and Mech 2006).

Most deer in the study area migrated from one of two winter concentration areas, roughly 30 km^2 each, and averaged 12-km and 25-km migrations to reach individual summer ranges, some up to 80 km distant (Nelson and Mech 1987). Deer migrated to summer ranges during late March and early April when summer range density was 1–3 deer/km^2 (Lenarz 2002). Parturition occurred primarily during the last week of May and first week of June (Kunkel and Mech 1994). Deer occupied 0.7–1.0 km^2 summer ranges (Nelson and Mech 1981) before returning to the winter concentrations during November to January, where densities were over 15 deer/km^2 (Nelson and Mech 1987). Gray Wolf (*Canis lupus*) predation and human hunting were the main causes of deer mortality (Nelson and Mech 1986). Wolves along with Black Bears *(Ursus americanus)* were major predators of newborn fawns during their first weeks of life (Kunkel and Mech 1994).

Methods

I captured adult does during February-April when they occupied winter concentration areas (Nelson and Mech 1981). I anesthetized them (Kreeger 1996), extracted an incisor for aging (Nelson 2001), and fitted them with very high frequency (VHF) radio collars or Global Positioning System (GPS) collars (Merrill *et al.* 1998). I radio-tracked VHF-collared does from the air two to four times weekly. GPS-collared does yielded locations every hour, which I downloaded to a spreadsheet after remotely releasing the collars (Mech and Gese 1992) or retrieving them after mortality occurred.

I subsequently recaptured, recollared, and translocated while sedated, those adult does radio-tracked a minimum of 1 year. I translocated them 10-25 km outside their home ranges to unfamiliar (no previous radiolocations) and familiar (previous radio locations) release sites. I separated the two groups when describing and analyzing their movements. I recorded the number of days they used to return to their home ranges, or if not returning, the number of days radio-tracked until they died or their radio-collars expired.

I used data from both VHF- and GPS-collared does to measure propensity to return to home ranges after being translocated, but only data from GPS-collared does to describe and quantify movements. To provide experimental controls for comparing with translocated GPS-collared does rearing fawns, I captured and released does at their capture sites wearing GPS collars programmed to record hourly locations starting 16 May, 1 week before parturition and continuing through the first 3 weeks of fawn rearing to 23 June.

I measured area used by GPS-collared does by calculating minimum convex polygons (MCP) of their locations (Mohr 1947). I differentiated two modes of movement: directional travel and all other movement based on rate (m/h) measured by distance between hourly locations. I identified and defined travel based on migrating GPS-collared deer traveling 1.5 km/h (SD = 0.6, n = 27, Nelson *et al.* 2004). Because 95% of their hourlymigration travel exceeded 300 m/h and was sustained for 3–6 h per travel periods (Nelson *et al.* 2004), I classified as "travel" in this study, directional movement of > 300 m during each of at least 3 sequential hours. These criteria separated directional travel from all other movements, including those that slowed, circled, or deviated from directional movement.

I contrasted movement behaviours and MCPs of translocated GPS-collared does with those of control GPS-collared does and further compared their hourly movement rates during each week starting 16–23 May and during the first 3 weeks of the fawn-rearing period. I assumed the timing of parturition based on a pattern of spatially constricted locations by parturient does (Kunkel and Mech 1994). This sampling corresponded to the following biological ontogeny: a period before fawns are born; the first week of fawn rearing, which requires maternal care and defensive behaviour by the doe and suckling and hiding behaviour of fawns; the second week of fawn rearing, when the transition from hiding to running begins as a response by fawns to danger (Jackson *et al.* 1972); the third week of fawn rearing, when fawns generally run from danger.

I analyzed hourly movement rates by estimating means and 95% confidence limits (Cherry 1998; Anderson *et al.* 2001; Johnson 2002). I further compared hourly movement rates of translocated does with those of control does during each week sampled in the prefawn and fawn-rearing periods, by using *t*-tests and accepting statistical significance at $P < 0.05$ and when 95% CLs on the mean differences did not include zero.

I followed the American Society of Mammalogists' guidelines (Sikes and Gannon 2011) and the Animal Care and Use Committee study plan 2700202, Patuxent Wildlife Research Center, United States Fish and Wildlife Service.

Results

I captured and radio-collared 26, 1–13 year-old does (median = 6 years old) during February-April 1995–2007. Of the 26 does, I radio-tracked 17 for 1–4 years (median = 2 years) before recapturing and translocating them 10-25 km (median = 13 km) outside their current home ranges. I captured two of them a third time and translocated them to familiar sites that they previously occupied but located outside their current home ranges. I released the remaining nine does at their capture sites to serve as experimental controls for hourly movement comparisons to translocated does during the fawn rearing period.

Radio-tracking of translocated does yielded 2–111 (median = 46) locations from 12 VHF-collared does and 709–4150 (median = 2605) locations from seven GPS-collared does, acquiring 58–95% (median = 84%) of potential locations. Nine control GPS-collared does yielded 341–655 (median = 453) locations, 36–70% (median = 50%) of potential locations.

Return to home ranges

Twelve of 17 (71%) does that were translocated to unfamiliar sites returned to their home ranges. Ten returned within 1–89 days (median = 22 days) and the other two returned 1.3 and 3.2 years later. The remaining five does failed to return to home ranges as three died and the collars on two others expired (80–275 days, median 174 days). The two does translocated to familiar sites outside their current home ranges also returned to their home ranges.

GPS-collared does released at unfamiliar sites

From March through September 2004 through 2006, five translocated GPS-collared does released at unfamiliar sites traveled directionally, circled, backtracked, and returned to or toward their release sites (Table 1, Figure 1). Does 8164, 8180, and 8252 roamed extensively and the other two (7958 and 8172) traveled directly. Doe 7958 moved directly to her adult summer range to which she had dispersed 3 years earlier as a 1 year old. The bearings and distances for her dispersal movements include the region of her release site, although she was never located there. Doe 8172 moved in a direction away from her home range before backtracking 76% of the distance to her release site (Table 1). Hourly movement rates combined comprised 4% travel and 96% nontravel movement (Table 1). The does moved ten times faster when traveling than at other times (877 m/h vs. 83 m/h, respectively, Table 1).

GPS-collared does released at familiar sites

In late March and early April, I translocated GPS-collared does 7904 and 7940 to familiar sites: 7904 to

TABLE 1. Rates and patterns of travel and nontravel movement* of translocated GPS-collared adult female White-tailed Deer (*Odocoileus virginianus*) in northeastern Minnesota, March-September, 2004-2007.

Doe	Travel period	Travel rate Mean, m/h	95% CL	*n*	Nontravel rate Mean, m/h	95% CL	*n*	Movement pattern MCP, km^2	Direct travel, km	No. of locations
Released at unfamiliar site										
7958	1–30 Mar	NA	NA	NA	54	9	521	NA	22	588
8164	22 Mar – 7 Sep	840	151	28	56	4	1859	595	NA	2367
8172	9 Apr – 30 Sep	1118	355	19	90	7	2083	NA	42	808
8180	22 Mar – 21 Sep	893	57	243	96	6	3707	309	NA	4140
8252	2 Apr – 7 Jul	803	96	96	83	6	1939	180	NA	2128
Combined	—	877	48	386	83	3	10109	NA	NA	NA
Released at familiar site										
7904	28 Mar – 16 Apr	881	170	28	85	17	394	143	NA	435
7940	1–9 Apr	1064	513	5	56	15	72	NA	22	109
Combined	—	909	155	33	85	14	465	NA	NA	544

Note: CL = confidence limits, MCP = minimum convex polygon, NA Not applicable

*Travel is directional movement of > 300 m during each of at least 3 sequential hours; nontravel is all other movements, including those that slowed, circled, or deviated from directional movement.

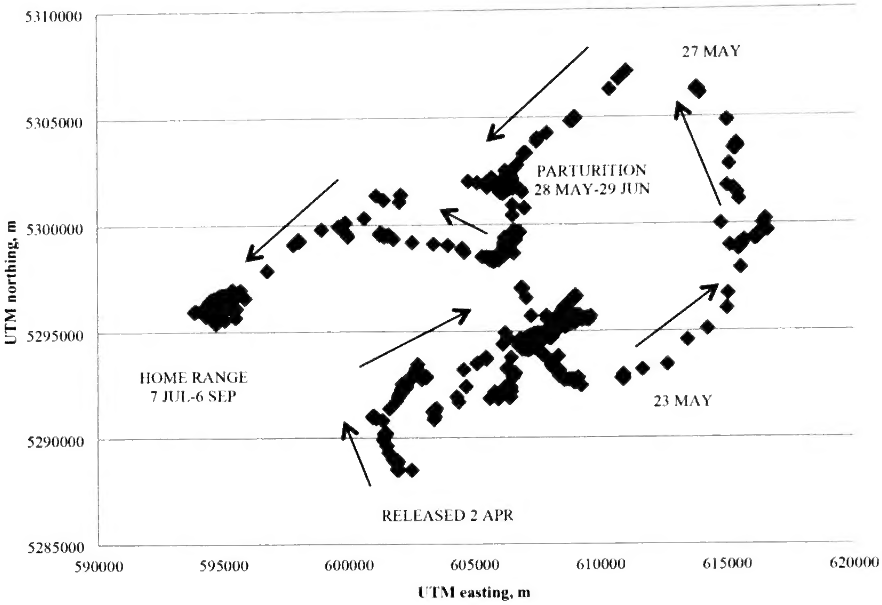

FIGURE 1. The 3510 hourly locations recorded for GPS-collared White-tailed Deer (*Odocoileus virginianus*) doe 8252 from 2 April, when she was released at an unfamiliar site 10 km from her home range, to 6 September 2006 in northeastern Minnesota. Arrows depict her general direction of travel starting at the release site and arriving at her home range on 7 July.

a previous release site that she had used 7 years earlier and 7940 to her natal home range from which she had dispersed 5 years earlier as a 1 year old.

Doe 7904 traveled extensively, circling and backtracking for 19 days before reaching her winter home range (Table 1). She remained there 15 h before migrating directly to her summer range. Doe 7940 traveled directly for 22 km, including 4 km of backtracking to reach her winter range in 8 days (Figure 2). She remained there 8 days before migrating 11 km to her summer range. Their combined hourly movement rates comprised 7% travel and 93% nontravel movement (Table 1). They moved ten times faster when traveling than at other times (909 m/h vs. 85 m/h, Table 1).

GPS-collared does during fawn rearing

Translocated GPS-collared does 8164, 8172, 8180, and 8252 stopped their extensive travel in mid-May before parturition, which began for them and nine control GPS-collared does between 25 May and 6 June (median = 31 May). During 12–28 (median = 23) sequential days of fawn rearing, both groups occupied 0.2–1.3 km^2 (median = 0.5 km^2).

Translocated and control does moved at the same mean hourly rates during 7 days in mid-May before fawn rearing and also during the first week of fawn rearing (Table 2). Control does moved faster than translocated does during the second week of fawn rearing, but not in the third week (Table 2). Translocated does permanently departed their fawn rearing areas after

TABLE 2. Rate of movement of translocated and control GPS-collared adult female White-tailed Deer (*Odocoileus virginianus*) in northeastern Minnesota a week before parturition (16–23 May 2001-2006) and during three weeks after parturition while rearing fawns.

Period	Translocated does Mean, m/h	95% CL	*n*	Control does Mean, m/h	95% CL	*n*
Preparturition (1 week)	79	9	586	88	8	639
Fawn rearing						
First week	66	6	524	74	6	707
Second week	83*	9	475	109*	9	598
Third week	97	13	356	105	8	643

Note: CL = confidence limits.
*Significant difference between translocated and control does ($p < 0.005$, *t* test).

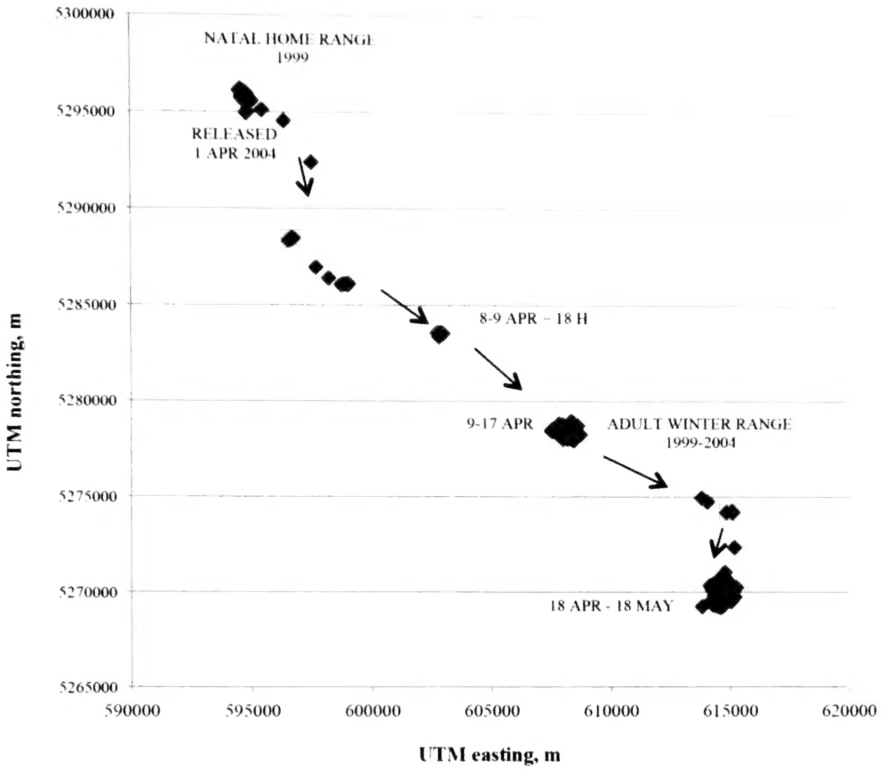

FIGURE 2. The 710 hourly locations, recorded between 1 April and 18 May 2004, for GPS-collared White-tailed Deer (*Odocoileus virginianus*) doe 7940 captured on her winter range and translocated 22 km to a familiar site (her natal home range) 5 years after natal dispersal. Arrows depict her general direction of travel starting at her release site, traveling 22 km, arriving on her adult winter home range on 9 April, subsequently traveling 11 km further to her adult summer home range, and arriving on 18 April.

12–45 days (median = 26 days) and continued traveling, while control does remained on their home ranges.

Discussion

All translocated does left their release sites, which had resident deer present, suggesting that the resources for deer survival were present. Thus, lack of habitat appeared an unlikely factor influencing their departure. Aggression by resident deer toward the translocated does can also be excluded as a factor, as elsewhere in the study area, sympatric wintering deer moved independently of each other, suggesting that competition for space was not influencing their movements (Nelson and Sargeant 2008). Similarly, Jones *et al.* (1997) observed no effect on movement of resident deer from the presence of translocated deer. Although conflict is observed at artificial feeding sites, which attract large numbers of deer, such disputes appear restricted to feeding behaviour (Ozoga 1972).

There was large variation in the amount of time taken to return to home ranges despite the fact that 87% of the does were translocated similar distances (13–15 km). I previously found that female yearlings made 7–22-km forays beyond their natal ranges (Nelson 1998), and some dispersed 18–168 km to new home ranges (Nelson 1993). Thus, spatial memories established during exploratory or dispersal movements could have been one factor influencing variation in return time over similar distances. Conceivably, some does encountered areas they recognized from previous exploratory or dispersal movements and then navigated accordingly to return to familiar space. Others not encountering familiar areas would necessarily spend more time roaming if spatial memory was the primary mechanism they used as they attempted to return to home ranges.

The movements of four of five GPS-collared does translocated to unfamiliar release sites suggest that they were looking for familiar space. Their extensive travel far exceeded that necessary to acquire the resources for daily survival evinced by adult does in the study area that were occupying home ranges < 1% the size of spaces traveled by translocated does (Nelson and Mech 1981). Their movements further suggest that translocated does simultaneously developed new spatial memories, evidenced by backtracking and returning to release sites.

The direct travel to her home range by the fifth GPS-collared doe suggests that the release site was part of the spatial memory she had developed during natal dispersal movements in the region of the release site as she established her adult home range. Direct travel by the two GPS-collared does released on familiar sites after being absent from them 5 and 7 years also indicates that they recognized their surroundings, although only one traveled like deer migrating annually between summer and winter home ranges (Nelson *et al.* 2004). The additional roaming, circling, and backtracking of the other doe hints at variation in the longevity of spatial memory and highlights the challenge of understanding and including it in models of animal movement.

The movements of the one doe translocated to an unfamiliar release site, traveling directly and backtracking toward her release site, contrasts sharply with her roaming cohorts. Given the small sample size and the fact that she was nonmigratory before being translocated, it is difficult to interpret her movements. She may have been behaving similar to three translocated deer that appeared to invoke memory of their previous migration pattern (Nelson 1994). Migrating Siberian roe deer (*Capreolus pygarus*), captured and translocated to unfamiliar areas while migrating, mimicked the same migration direction and distances as their cohorts (Danilkin *et al.* 1994). These examples suggest that at least two cognitive processes operate to achieve spatial orientation: one depending on memory of bearing and distance patterns to direct movement, and another involving roaming and searching for familiar space to determine direction of travel.

When translocated GPS-collared does stopped traveling just before parturition, they moved at the same hourly rates as control GPS-collared does and, subsequently, constricted their movements, as did control does, indicating that both groups gave birth and cared for their fawns (Nelson and Mech 1981; Ozoga *et al.* 1982; Kunkel and Mech 1994). The similar movement rates of both groups during the first week of fawn rearing suggest that translocated does may not have experienced any negative behavioural or physiological effects from their extensive travel before parturition. The increased rate of movement by control does, compared with translocated does, in the second week of fawn raising suggests possible differences as fawns matured. However, in the subsequent week, both groups moved at the same rate indicating an overall pattern of similar movement rates before and while rearing fawns.

The duration of restricted movement of does after giving birth further indicates that they nurtured their fawns beyond the period of fawn concealment and inactivity, well into the period when fawns regularly follow their mothers (Jackson *et al.* 1972). This further indicates adequacy of nutrition for maintenance as well as that needed to sustain lactation. I do not know if the fawns survived and followed their mothers when they continued roaming. Regardless, the relevant and overriding result is that the biological imperative of parturition and fawn rearing took temporary precedence over travel for the translocated does. This is a clear example of changes in movements determined by opposing internal processes: one directing parturition and nurturing behaviour and the other emanating from the capacity for spatial cognition and the propensity to occupy familiar space.

All translocated does left their release sites, and those surviving with transmitting radio-collars returned to their home ranges. The translocated GPS-collared does did this despite having met their nutritional and physiological demands while traveling through hundreds of square kilometres, three orders of magnitude larger than home ranges of adult does. Thus they moved continually beyond daily field of perception to eventually arrive at the exact site they occupied before being translocated. This clearly demonstrates not only the capacity for spatial memory, but also the propensity to return to familiar space. The extremely aberrant roaming of the GPS-collared does can only be understood as searching the landscape for space that was remembered and recognized when finally found.

The dominant paradigm of ungulate movement is based on the premise that movement is directed by innate optimal foraging in the field of perception. Mathematical modeling has accepted this premise, ignoring behavioural mechanisms, such as the influence of spatial memory (Gautestad and Mysterud 2005). However, it has become increasingly clear that spatial memory plays an integral role in animal movement and must be included in models to achieve biological reality in predicting movements. Fagan *et al.* (2013) recognized this as part of an "emerging research interface" of behavioural ecology, cognitive science, animal tracking, and quantitative ecology. The findings herein contribute to their call for experimental evidence of spatial memory and further elucidate its pervasive role in the spatial ecology of White-tailed Deer.

Acknowledgements

This research was supported by the United States Geological Survey, United States Department of Agriculture North Central Research Station, and Special Projects Foundation funding to L. D. Mech. I thank L. D. Mech for his support of the study and review of the manuscript. I also thank associate editor Garth Mowat and two anonymous reviewers for comments and suggestions for improving the manuscript. I thank 160 volunteer wildlife technicians who assisted in live capture of deer and who retrieved collars. I also thank the pilots of the U.S. Forest Service for skillful and safe flying.

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Received 16 January 2014
Accepted 18 June 2014

Whitebark Pine (*Pinus albicaulis*) Seeds as Food for Bears (*Ursus* spp.) in Banff National Park, Alberta

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Hamer, David, and Ian Pengelly. 2015. Whitebark Pine (*Pinus albicaulis*) seeds as food for bears (*Ursus* spp.) in Banff National Park, Alberta. Canadian Field-Naturalist 129(1): 8–14.

The large, nutrient-rich seeds of Whitebark Pine (*Pinus albicaulis* Engelmann) are important food for bears (*Ursus* spp.) in Yellowstone National Park. In Banff National Park, studies have shown that American Black Bears (*Ursus americanus*) eat these seeds, but little additional information is available. We studied Whitebark Pine in Banff National Park to address this information gap. Because bears obtain Whitebark Pine seeds from Red Squirrel (*Tamiasciurus hudsonicus*) middens, our objective was to measure the abundance, habitat characteristics, and use by bears of middens in Whitebark Pine forests. A second objective was to determine whether Grizzly Bears (*U. arctos*) in Banff National Park also eat Whitebark Pine seeds. In 2011–2012, we ran 29 ha of 20–50 m wide transects at 10 sites with accessible Whitebark Pine stands and found 0–3.7 middens/ha (mean 1.23, SD 1.17, $n = 10$). Midden density was weakly related to total basal area of all conifers but not to basal area of Whitebark Pine. Middens were located in the upper subalpine at an average elevation of 2110 m (SD 90, $n = 8$) on 41–248° facing slopes with a mean steepness of 28° (SD 5, $n = 8$). Bears had excavated middens at all eight sites where we found middens; at the remaining two sites, middens did not occur within our transects. Overall, 24 (67%) of the 36 middens located in our transects had been dug by bears. In October 2013, we searched areas where three global positioning system (GPS)-collared Grizzly Bears had been located in late September 2013 and found five recently dug middens located less than 6 m from GPS fixes. These observations are, to our knowledge, the first conclusive evidence that Grizzly Bears in Banff National Park eat Whitebark Pine seeds. Because Whitebark Pine occurs at high elevations on steep slopes where human use is low, this resource may be important in keeping bears in habitat where risk of human-caused mortality is lower. Our results may assist managers responsible for conservation of bears in Banff National Park, where both American Black Bears and Grizzly Bears are subject to high levels of human-caused mortality.

Key Words: American Black Bear; Banff National Park; Grizzly Bear; midden; *Pinus albicaulis*; Red Squirrel; *Ursus americanus*; *Ursus arctos*; *Tamiasciurus hudsonicus*; Whitebark Pine; seeds

Introduction

The large, nutrient-rich seeds of Whitebark Pine (*Pinus albicaulis* Engelmann) are a major food for Grizzly Bears (*Ursus arctos*) and American Black Bears (*U. americanus*) in the Greater Yellowstone Ecosystem (GYE; Fortin *et al.* 2013). As stated by Mattson and Reinhart (1997:926): "When whitebark pine seeds are abundant, grizzly bears [in the GYE] eat virtually nothing else." Mattson *et al.* (1992) found that in years of high seed availability, GYE Grizzly Bears were half as likely to use areas within 5 km of roads or within 8 km of other developments because Whitebark Pine's high elevation distribution typically is remote from human facilities. In contrast, in years of small Whitebark Pine seed crops, mortality of adult female Grizzly Bears averaged 2.3 times higher, and mortality of subadult males averaged 3.3 times higher than in years of large seed crops, which the authors attributed to the tendency of bears to range closer to human facilities in years of pine seed scarcity.

Use of Whitebark Pine seeds by bears in Canada has not been clearly described. Whitebark Pine seeds were recorded in the diet of American Black Bears in Banff National Park (Kansas *et al.* 1989; Raine and Kansas 1990), although information on habitat use was limited to the general observation that American Black Bears feeding on Common Juniper (*Juniperus communis* L.) cones, Common Bearberry (*Arctostaphylos uva-ursi* [L.] Sprengel) fruits, and Whitebark Pine seeds frequented higher elevations in moderate to steeply sloping, south-facing, sub-xeric pine forests. Seeds of Whitebark Pine were also eaten by a radio-collared Grizzly Bear in Yoho National Park in 1 year of a 3-year study along the Continental Divide immediately west of Banff National Park (Raine and Riddell 1991). No habitat information was provided other than that this feeding occurred on high-elevation slopes.

McLellan and Hovey (1995) noted that Whitebark Pines were common in their southeast British Columbia study area, but they observed only one case of Grizzly Bears apparently feeding on seeds, and Whitebark Pine seeds did not occur in their sample of scats. In southwestern Alberta, Hamer *et al.* (1991) did not record Grizzly Bear use of Whitebark Pine seeds in Waterton Lakes National Park. In central Alberta, Whitebark Pine seeds were not recorded in Grizzly Bear food-habit studies conducted in Jasper National Park, Banff National Park, or the Jasper–Edson area (Russell *et al.*

1979; Hamer and Herrero 1987; Munro *et al.* 2006), although the Banff study area was northeast of the zone of Whitebark Pine abundance in the park. A Grizzly Bear study (Wielgus 1986) and an American Black Bear study (Holcroft and Herrero 1991) in Kananaskis, immediately east of Banff National Park, also did not record bear use of Whitebark Pine seeds.

We studied Whitebark Pine in and near Banff National Park during 2011–2013 to address the lack of specific research regarding use of pine seeds by bears in this area. Because Mattson and Reinhart (1997) found that all Whitebark Pine seeds eaten by bears in the GYE were obtained from Red Squirrel (*Tamiasciurus hudsonicus*) middens, our principal objectives were to record the abundance, habitat characteristics, and evidence of use by bears of Red Squirrel middens in Whitebark Pine forests. Because field evidence of bear use of middens is not species specific, we also checked areas where radio-collared Grizzly Bears had been located to address the specific question: do Grizzly Bears in Banff National Park eat Whitebark Pine seeds?

Study Area

Banff National Park occupies 6641 km^2 in the central Rocky Mountains of Alberta, Canada. The park extends eastward from the Continental Divide to encompass mountainous habitat of both the Main Ranges and the more easterly, more arid Front Ranges. Elevation in Banff National Park ranges from 1330 m to 3610 m with the tree line at roughly 2300 m. The subalpine zone is at approximately 1500–2350 m, with the upper subalpine (generally cooler and wetter, with deeper and longer lasting snow) beginning at about 2000 m (Achuff 1982). Our study sites were between 1900 m and 2300 m where Whitebark Pine occurs.

We worked in Whitebark Pine stands that exhibited little mortality from White-Pine Blister Rust (*Cronartium ribicola*) or Mountain Pine Beetle (*Dendroctonus ponderosae*). Banff National Park currently has a low rate of White-Pine Blister Rust infection compared with locations north and south along the Rocky Mountains (Smith *et al.* 2008, 2013). Because we located study sites in Whitebark Pine stands, Whitebark Pine was often co-dominant in our plots. Based on basal areas recorded during our analyses, the relative abundance of Whitebark Pine was 38%, Interior Spruce (*Picea engelmannii* var. *engelmannii* × *P. glauca*) 32%, Subalpine Fir (*Abies lasiocarpa* [Hooker] Nuttall) 19%, Lodgepole Pine (*Pinus contorta* Douglas ex Loudon) 11%, and Subalpine Larch (*Larix lyallii* Parlatore) 1%. The understory included submesic Soapberry (*Shepherdia canadensis* [L.] Nuttall)–Common Juniper–Common Bearberry communities; mesic Grouseberry (*Vaccinium scoparium* Leiberg ex Coville) and Grouseberry–Soapberry communities; and subhygric Subalpine Fir (saplings)–False Azalea (*Menziesia ferruginea* J. E. Smith syn. *M. glabella*)–feathermoss (e.g., *Hylocomium splendens*, *Pleurozium schreberi*) communities (Corns and Achuff 1982).

Methods

Transects

We established belt transects at 10 sites in Whitebark Pine forests to measure the density, habitat characteristics, and use by bears of Red Squirrel middens (i.e., locations where squirrels cache large numbers of conifer cones, shred these cones to obtain seeds, and thus create conspicuous deposits of organic material). We identified Whitebark Pine stands from aerial survey (I. Pengelly and A. Buckingham, Parks Canada, unpublished data), knowledge of Whitebark Pine stands in the park, and reconnaissance from roads and trails. At 71% of our surveyed areas, Whitebark Pine basal area was greater than 4 m^2/ha. We established six transect sites in the main Bow Valley, two in the North Saskatchewan watershed at the north end of the park, and two 0.3 and 2.4 km west of Banff National Park in Kootenay and Yoho national parks, respectively. The average distance between transect sites was 57 km (range 0.2–157 km). Transect sites were 0.4–3.8 km from road access. Fieldwork was conducted from 7 September to 2 October 2011, except at one partly surveyed site where we completed work in 2012.

We used a transect width that allowed the enclosed area to be accurately surveyed without excessive coursing up and down slope. Most transects (51% of hectares surveyed) were 30 m wide and conducted by two people. We also ran 20-, 40-, and 50-m wide transects with one, three, and four people, respectively. We ran transects on the elevational contour of the start point, with one person maintaining this elevation so that middens near a transect edge could be accurately placed inside or outside of the transect.

Transects were 114–607 m long and ended either at a natural feature, such as an avalanche slope or rock talus, or after a preselected distance, commonly 200 or 400 m. Transect length was measured with a hand-held global positioning system (GPS) unit. At the end point, a new transect was typically run in the reverse direction, starting at a preselected distance up or down slope.

Only middens whose centres were inside a transect were recorded. A midden centre was defined as the centre of the "midden tree" (for those formed around the base of a large-diameter tree) when this was unambiguous; otherwise, it was the intersection of the axes of midden length and width. Only middens with conifer-cone debris more than 20 cm deep and covering more than 10 m^2 (> 6 m^2 if depth > 30 cm) were included. These criteria were used to exclude the numerous smaller deposits of cones and cone debris across the landscape that result from squirrel feeding activity. We also defined a secondary (diffuse) midden (Gurnell 1984) as a smaller midden (but meeting our criteria of minimum depth and area) whose centre was also within the transect and that was less than 25 m from a larger midden (average distance 13.8 m). These secondary middens were assumed to be part of the resident squirrel's caching and feeding activity (Gurnell 1984) and, hence, were not analyzed separately to avoid pseudoreplication.

At each midden, we measured midden length (the longest axis of the midden) and width (the greatest dimension at right angles to the long axis) and multiplied these numbers to obtain midden area (Mattson and Reinhart 1997). We recorded location and elevation using a hand-held GPS unit, slope aspect and steepness using a compass with built-in clinometer, and conifer basal area using a 2 m^2/ha prism. Visible Whitebark Pine cones were counted, but we did not disturb middens to tally buried cones. Excavated middens and middens with nearby bear fecal deposits (scats) containing pine seeds were recorded as used by bears.

We also recorded site characteristics at systematic points along transects (null plots). These null plots were placed 160 m from the last midden or transect starting point when no midden occurred within 200 m. We measured distances with a GPS unit and used these distances to locate null plot centres without bias.

GPS-collared Grizzly Bears

During late October 2013, we searched areas where three GPS-collared Grizzly Bears had been located. These bears were collared by Parks Canada for another study and generated GPS locational fixes every 20 minutes to 4 h. We selected a small subset of fixes from those obtained during 7–29 September 2013 in Banff National Park, 1.9–9.0 km from vehicle access, and in upper subalpine areas where Whitebark Pines are found. Google Maps (satellite view) was used as a layer in the geographic information system, QGIS (open-source software, version 2.0.1), to exclude fixes in non-forested habitat. Fixes were searched for signs of bear activity. Red Squirrel middens, if present near the fix, were examined in the same way as those located on our transects.

Data analysis

Sites were our sampling units. For each transect site, we assessed the relation between midden density and conifer basal area and between midden density and the proportion of Whitebark Pines using the linear model in R (open-source software, version 3.0.2). Because of our small sample size, we present differences in characteristics among middens obtained by transecting, middens located at GPS sites, and plots located at null sites visually using box-and-whisker diagrams in R. Secondary middens were excluded from all analyses except for calculation of total middens per hectare.

Results

Middens located by transecting

The mean density of Red Squirrel middens in our 10 transect sites was 1.23 middens/ha (SD 1.17, Table 1) and 1.81 middens/ha (SD 1.84) if secondary middens were included. Mean midden size was 97 m^2 (SD 64, range 30–218 m^2, $n = 8$).

All middens contained Whitebark Pine cone scales, but we found few cached Whitebark Pine cones in 2011 compared with the hundreds we found in several middens during a 1-day pilot project in 2010. In 2011, the three largest caches of Whitebark Pine cones held 195, 67, and 7 cones. No cached Whitebark Pine cones were found in the three middens located at the site completed in 2012.

TABLE 1. Results of transect survey of Red Squirrel (*Tamiasciurus hudsonicus*) middens conducted in Whitebark Pine (*Pinus albicaulis*) stands in and adjacent to Banff National Park, Alberta, 2011–2012.

Transect site	Area surveyed (ha)	No. middens	Mean slope aspect* (°)	Mean slope steepness* (°)	Mean elevation* (m)	Mean basal area of Whitebark Pine* (m^2/ha)	Mean basal area of other conifers* (m^2/ha)	Midden density (no./ha)	Mean midden area (m^2)	Evidence of use by bears
A	4.17	2	41	20	2000	7.0	26.0	0.48	137	Dug, scat
B	3.01	3	240	31	2150	6.0	32.0	1.00	96	Dug, scat
C	2.52	0	265	31	2020	9.0	20.0	0	—	—
D	2.06	4	189	33	2210	27.0	7.2	1.95	39	Dug
E	2.99	11	176	30	2210	11.6	24.7	3.68	51	Dug, scat
F	4.43	6	190	30	2100	10.3	32.7	1.36	68	Dug
G	1.84	0	240	33	1990	6.7	8.0	0	—	—
H	2.44	6	248	22	1960	22.0	27.0	2.46	218	Dug, scat
I	2.05	1	230	34	2150	10.0	24.0	0.49	135	Dug
J	3.61	3	185	23	2070	18.7	8.9	0.83	30	Dug, scat
Total	29.12	36	—	—	—	—	—	—	—	—
Mean	—	—	200	29	2090	12.8	21.1	1.23	97	—
SD	—	—	64	5	90	7.2	9.7	1.17	64	—

*At null plots if no middens occurred at that transect site.

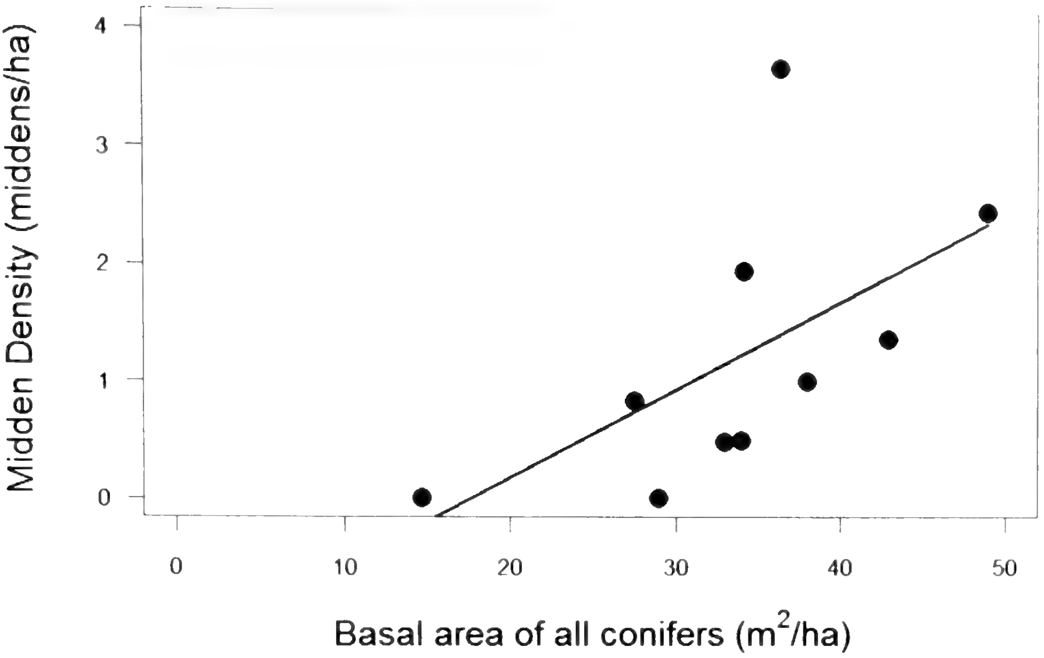

FIGURE 1. Relation between density of Red Squirrel (*Tamiasciurus hudsonicus*) middens and conifer basal area in 10 Whitebark Pine (*Pinus albicaulis*) belt transect sites in and adjacent to Banff National Park, Alberta, 2011–2012.

We found a weak positive relation between midden density and forest basal area, with total basal area of conifers explaining 27% of the variation in the data (adjusted $r^2 = 0.272$; $F = 4.36$; 1, 8 df; $P = 0.07$; Figure 1). We did not find a relation between midden density and basal area of either Whitebark Pines ($P = 0.2$) or other species of conifer ($P \geq 0.3$) or between midden density and the proportion of total conifer basal area accounted for by Whitebark Pine ($P = 0.7$).

Middens had been excavated by bears at eight of the 10 transect sites; at the two remaining sites, we did not record any middens within the transects (Table 1). Overall, 24 (67%) of the 36 middens found in our transect sites had been dug by bears. Eight (33%) of the 24 dug middens had been excavated recently (i.e., late summer or early autumn 2011). We also found bear scats containing Whitebark Pine seeds at five of the 10 transect sites (Table 1).

Null plots had similar elevation, slope aspect, slope steepness, and basal area of Interior Spruce compared with midden plots (Figure 2a, b, c, and g). However, the basal areas of all conifers, Whitebark Pine, and Subalpine Fir were, respectively, about 1.3, 1.5, and 2.0 times greater at middens than at null plots (Figure 2e, f, and h). Middens tended to occur on less-steep slopes (mean 27.7° [SD 5.5, $n = 8$] than null plots (mean 31.7° [SD 3.4, $n = 8$]).

Use of middens by GPS-collared Grizzly Bears

We located recently dug middens at three GPS fixes of an adult female Grizzly Bear and at two fixes of a subadult male Grizzly Bear. All five dug middens were less than 6 m from GPS fixes and, thus, were linked to Grizzly Bear activity. Bear scats containing Whitebark Pine seeds occurred at three of these GPS sites. The central axes of Whitebark Pine cones, some with attached cone scales, numbered > 100, > 100, 30, 1, and 0 at the five sites. The midden with no identified cone axes contained Whitebark Pine cone scales.

We searched more than 15 satellite fixes from a third GPS-collared Grizzly Bear, at four locations occurring over 8 km linear distance in the park. We did not find Whitebark Pine feeding signs or Whitebark Pine stands at or near any of the fixes from this adult female.

The five middens found at fixes of GPS-collared Grizzly Bears had habitat characteristics notably similar to those of the middens we recorded from transects, including mean elevation (2150 m vs. 2110 m), aspect (210° vs. 190°), and slope steepness (29° vs. 28°). Mean midden size (94 m^2 vs. 97 m^2) and total conifer basal area (35 m^2/ha vs. 37 m^2/ha) were also similar. However, mean Whitebark Pine basal area was 7 m^2/ha at GPS-located middens but 14 m^2/ha at transect middens. Contributing to this difference was one GPS-located midden on a bench with a 16° slope, with no Whitebark Pines at the site (although Whitebark Pine trees were abundant on a steep, 37° slope 35 m away). These comparisons are displayed non-parametrically (i.e., using medians and quartiles) in box-and-whisker diagrams (Figure 2). Our GPS sample is small, but the notable overall similarity between the GPS data and the transect data supports the validity of our midden sampling by transect.

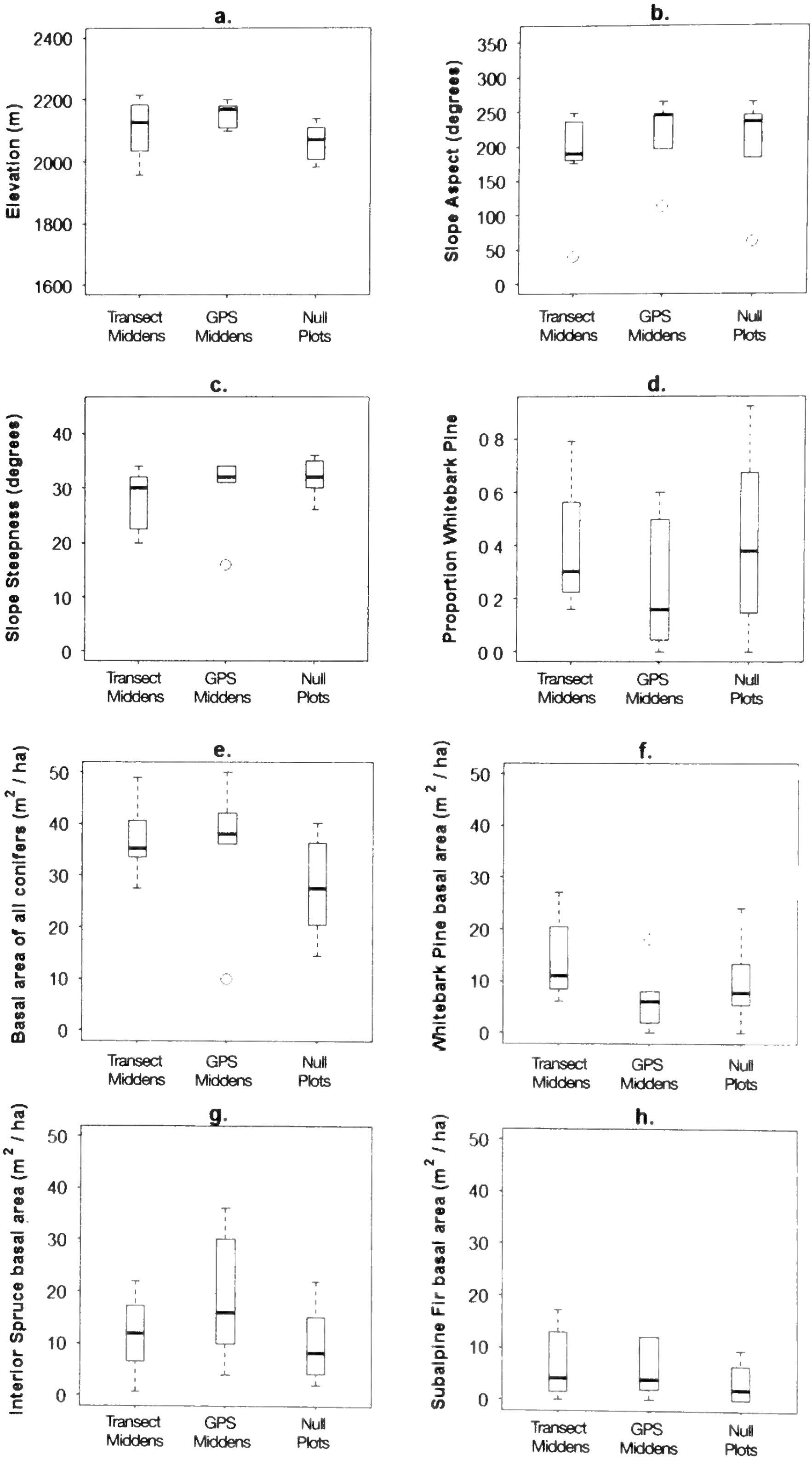

FIGURE 2. Comparison of habitat characteristics at 36 Red Squirrel (*Tamiasciurus hudsonicus*) middens located in eight belt transect sites, five middens within 6 m of satellite fixes of two GPS-collared Grizzly Bears (*Ursus arctos*), and 27 null plots established systematically at 200-m intervals when no midden occurred within a transect for that 200-m distance (8 sites) in Whitebark Pine (*Pinus albicaulis*) stands in and adjacent to Banff National Park, Alberta, 2011–2013. (a) elevation; (b) slope aspect; (c) slope steepness; (d) ratio of Whitebark Pine basal area to total conifer basal area; and basal area of; (e) all conifers; (f) Whitebark Pine; (g) Interior Spruce (*Picea engelmannii* × *P. glauca*); and (h) Subalpine Fir (*Abies lasiocarpa*). Diagrams show median (band inside box), first and third quartiles (top and bottom of box), 1.5 times the interquartile range (ends of whiskers); and outliers beyond the 1.5 interquartile range limits (circles).

Discussion

Our observations of five recently dug Red Squirrel middens within 6 m of fixes obtained from two GPS-collared Grizzly Bears during September 2013, plus the associated scats containing Whitebark Pine seeds, are, to our knowledge, the first conclusive evidence that Grizzly Bears in Banff National Park eat Whitebark Pine seeds.

We found that 67% of the middens located by transecting had been excavated by bears. All eight transect sites where middens were recorded contained excavated middens; however, we did not identify the species of bear involved in these excavations. In 2011, when we ran most transects, middens contained few cached Whitebark Pine cones, and we did not find recently deposited bear scats containing Whitebark Pine seeds as required for DNA sampling. Hence, we were unable to differentiate American Black Bear use from Grizzly Bear use in our transect sites. These results contrast with our 1-day pilot project in 2010 when we found four fresh scats containing pine seeds within 2 ha at a site where we established transects in 2011.

At our transect sites, Whitebark Pine basal area ranged from 0 to 27 m^2/ha, which is higher than the range of 0.2–7 m^2/ha reported for a study area in the nearby Willmore Wilderness Park (McKay and Graham 2010). The greater abundance of Whitebark Pine at our transect sites may partly explain why our mean midden density was greater than the 0.46 middens/ha reported by McKay and Graham (2010). Results from the GYE (Mattson and Reinhart 1997) were more comparable to ours, with Whitebark Pine basal areas of 2–23 m^2/ha and midden densities of 0.2 to 1.1/ha, although only active middens were tallied in that study. Our midden densities were 0–3.7/ha (Table 1). We did not differentiate between active and inactive middens because we judged that such categorization would be subjective and likely unreliable.

The mean basal areas of Whitebark Pine and Subalpine Fir were greater at midden plots than at null plots, but Interior Spruce basal area did not differ substantially. Because squirrels often establish middens at the bases of large trees, our midden basal areas may be high compared with those for the stand where they were located.

Null plots tended to occur on steeper slopes (26–36°) than middens (20–34°). Flatter microsites, including small benches interrupting the main slope, were locations for some middens. These microsites appeared to provide for the accumulation of midden material, allowing Red Squirrels to store cones in the organic debris. In contrast, on many steep slopes, it appeared that cones and conifer debris would readily disperse downhill from gravity and surface water flow.

Whitebark Pine seeds are a valued resource for bears in the GYE (Kendall 1983; Mattson *et al.* 1991; Fortin *et al.* 2013). Whitebark Pine cone abundance was the highest-ranked habitat covariate (along with year, season, sampling regime, and sex of Grizzly Bear) in six best models that explained Grizzly Bear survival in the GYE for 1983–2001 (Schwartz *et al.* 2006). Raine and Kansas (1990) identified Whitebark Pine seeds as part of the diet of American Black Bears in Banff National Park, and we have shown that Grizzly Bears in Banff National Park also eat these seeds.

American Black Bears in Banff National Park appear to be in decline because of high human-caused mortality (Hebblewhite *et al.* 2003). Grizzly Bears in Banff National Park are at the eastern limit of their range, inhabit one of the most intensively developed landscapes in the world where Grizzly Bears still occur, have the slowest reproductive rate of any Grizzly Bear population yet studied, and also experience high levels of human-caused mortality (Garshelis *et al.* 2005). Our study provides managers with information on a potentially important, nutrient-rich food that may give some bears the energy necessary for reproduction (Rogers 1976), and that, when abundant, can move bears into remote, steep habitat where risk of human-caused mortality is lower.

Acknowledgements

Financial support and GPS fixes were provided by Parks Canada. We are also grateful for the contributions of A. Buckingham, M. Didkowsky, A. Forshner, B. Fyten, S. Herrero, T. Jung, B. Low, J. Park, D. Verhulst, J. Whittington, L. Wiggins, N. Woode, and anonymous reviewers. Publication costs for this article were supported by the Thomas H. Manning Fund of The Ottawa Field-Naturalists' Club.

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Received 8 April 2014
Accepted 1 December 2014

Horse Ranching Increases Biodiversity in a Foothills Parkland Prairie in Northern Kananaskis Country, Western Alberta

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Catling, Paul M., Brenda Kostiuk, and Don Thompson. 2015. Horse ranching increases biodiversity in a foothills parkland prairie in northern Kananaskis Country, western Alberta. Canadian Field-Naturalist 129(1): 15–23.

Vascular plant biodiversity was evaluated in two adjacent sections of a continuous prairie glade. One section has been subject to moderate grazing by feral horses (*Equus ferus caballus*) in late summer and fall for the past 25 years, while the other has been protected. From 28 June to 2 July 2009, we recorded cover for all vascular plants present in ten 1-m^2 quadrats along five transects in each section. We calculated biodiversity measures, including species richness, evenness, and Shannon-Wiener and Simpson's diversity indexes. Horse grazing did not affect richness but significantly increased evenness. Grazing increased the Shannon-Wiener index, but did not affect the Simpson's index. Cover and frequency values for most species differed significantly between the two sites. Mountain Rough Fescue (*Festuca campestris* Rydberg) dominated the non-grazed site but several shorter grasses and different forbs dominated the grazed site. The plant community in the grazed areas can be seen as an earlier seral stage of the fescue community with a different contingent of plant species. Light grazing in part of the prairie glade increased overall plant diversity so that it provided more diverse animal habitat.

Key Words: Horses; Feral Horse; *Equus ferus caballus*; Mountain Rough Fescue; Festuca campestris; grazing; rangeland; vascular plants; biodiversity; richness; heterogeneity; eveness; Alberta; prairie foothills; Kananaskis; fescue grassland; shifting mosaic; patch dynamics; management

Introduction

A huge ecological cost is associated with livestock grazing in western North America, and continuing interest from conservation biologists is essential to ensure that management protects biodiversity (Fleischner 1994). The extensive literature on maintenance of healthy rangeland for livestock production in western Canada has led to an understanding that many rangeland species may benefit from moderate grazing (e.g., Tannas 2003a,b, 2004). However, the effects of grazing on biodiversity overall have not been sufficiently studied in Canada (Ollf and Ritchie 1998; Bai *et al.* 2001), although some important research is underway (e.g., the long-term east block grazing experiment in Grasslands National Park, see http://www.pc.gc.ca/eng/progs/np-pn/re-er/ec-cs/ec-cs01.aspx). Research to date has involved mostly cattle on the prairies and parklands and suggests that rangelands can be important in protecting biodiversity, although ecological integrity cannot be maintained if grazing pressure is too high (Trottier 1993; West 1993; McLaughlin and Mineau 1995).

The grazing ecology of the prairies of the Rocky Mountain foothills has been poorly studied, although they are the most diverse and complex of the fescue grasslands in Canada (Tannas 2003a, P.M.C. personal observation) and among the most productive grasslands in North America (Willms *et al.* 1996). The response of fescue grasslands to cattle stocking rates has been studied intensively at one site in the Porcupine Hills near Stavely, Alberta (Willms *et al.* 1985), but this site may not represent the foothills grasslands well. Only 5% of the grasslands remain in a pre-settlement condition (Vujnovic 1998), and they are now recognized as an endangered ecosystem (Trottier 2002). Increased precipitation in foothills prairies may make them more susceptible to grazing (Lauenroth *et al.* 1994).

There are currently over 350 000 feral horses (*Equus ferus caballus*) in Alberta, mostly used in recreation, and the number is increasing (Westar 2003*). Consequently, the demands for grazing land are also increasing, particularly in the foothills region. Grazing by horses has been shown to reduce plant species richness in some situations (Beever and Brussard 2000; Beever *et al.* 2008), but not in others (Detling 1998). These differences are likely a result of different grazing pressures.

With the effects of grazing generally requiring more study, especially in the foothills, and especially concerning feral horses, any situation providing data is an important study opportunity. We encountered such an opportunity in a foothills parkland prairie in northern Kananaskis Country of western Alberta. Here feral horses had been excluded for 25 years from half of a continuous fescue prairie glade, but rest rotation grazing at a specific carrying capacity was continued in the adjacent half. Data was collected to elucidate the effects of grazing by the horses on floristic diversity, as well as to obtain information for conservation and management.

Study Area

The area studied was within the Kananaskis Country in Bow Valley Provincial Park, at 51.0789°N and 115.0384°W. It consisted of a 5-ha prairie glade separated into two parts by a 10-m wide road allowance. The glade was surrounded by a semi-open woodland that included Trembling Aspen (*Populus tremuloides* Michaux), Lodgepole Pine (*Pinus contorta* var. *latifolia* Engelmann), Douglas Fir (*Pseudotsuga menziesii* var. *glauca* [Beissner] Franco), and White Spruce (*Picea glauca* [Moench] Voss). The park is a significant natural area with a rich diversity of flora and fauna (Pinel 1985*; Wallis and Wershler 1972*; Williams 1988*).

Requirements for comparison

To be able to attribute differences in vascular plant composition between the two sections to differences in grazing by feral horses, all other characteristics should be nearly the same. There is good evidence that this was the case. The two sections, "grazed" and "non-grazed," had similar gradual slopes, elevation, and very stony substrates, and the geology of the area was uniform (Rutherford 1927; Greenlee 1974; P.M.C. personal observation). The sections were separated only by a road and roadside fences, which clearly split a formerly continuous prairie glade, the edges of which remained well defined.

The entire glade was grazed by feral horses until 1984 (G. Cowley, Rafter Six guest ranch, personal communication) when grazing was discontinued on the south side (2.2 ha). On the north side (2.8 ha), grazing by horses was permitted at a moderate stocking level in the fall (15 August to 15 October) for 652 horse-days on approximately 22 ha of prairie which included the north half of the glade as well as open woods and other glades nearby. Over this period, both halves were subject to very light grazing by free-ranging Rocky Mountain Elk (*Cervus elaphus nelsoni*) and grazing to an even lesser extent by both Mule Deer (*Odocoileus hemionus*) and White-tailed Deer (*Odocoileus virginianus*) (R. Jaeger, park conservation officer, personal communication). The Rocky Mountain Elk (n = 100–160) also used the area from December to February as one of a large series of openings preferred because characteristic high wind and chinooks reduce snow accumulation and adjacent wooded areas provide cover (R. Jaeger, personal communication). Other grazing mammals, including various rodents, are scarce in this area of gravelly soils and are thought to have little impact on flora (P.M.C., personal observation).

Methods

Data collection and identification

Between 28 June and 2 July 2009, in each section (grazed and non-grazed), data on the presence and cover of species were gathered from 1-m^2 quadrats along five parallel transects at a 45° angle from the road. Ten quadrats, each 10 m apart, were placed on each transect, resulting in 50 quadrats on either side of the road (i.e., in each section). Cover for each species in each quadrat was estimated as a percentage of the 1-m^2 ground surface covered by living material of that species. The results were tallied so that species in the two sections could be compared with respect to both frequency and cover. No new species were recorded after 35 quadrats in either section suggesting that 50 was an adequate sample to describe the vegetation.

As grazing may sometimes result in more-or-less stable, heavily grazed and non-grazed patches, and increased heterogeneity may exist on a broad scale but not on a small scale (Willms *et al.* 1988), a relatively extensive sampling procedure, such as that used here, is advantageous in biodiversity comparison.

Most species were flowering at the time of sampling, and this aided in identification; the few exceptions were *Gentianella amarella*, *Solidago simplex* ssp., and *Symphyotrichum laeve* var. *geyeri*. Plants were identified using Packer (1994), Kuijt (1982), Hallworth and Chinappa (1997), and Tannas (2003a,b, 2004) as well as the online *Flora of North America* series (1993–2009).

The names mostly follow the recent compilation of Kartesz and Meachum (1999*) with some more recent changes from Brouillet et al. (2010+*). All species recorded in the prairie glade are listed in Appendix Table 1 with authorities, scientific names and frequently used common names. Voucher specimens are preserved in the National Collection of Vascular Plants of Agriculture and Agri-Food Canada in Ottawa (acronym DAO). Although the identifications are considered accurate, there were limitations. Some species were too immature to identify with certainty to the infraspecific level (e.g., *Solidago simplex*).

The dominant grass in the non-grazed area appeared to be *Festuca campestris* Rydberg, but this could be confirmed in only a few quadrats where it was flowering. As we believed that only one species of the rough fescue complex was present, all non-flowering plants were assumed to be this species. The site is near the boundary of the ranges of *Fesctuca campestris* and *F. altaica*. Kananaskis is located at 51° N, very close to the southern limit of *F. altaica* in the Canadian Cordillera (Pavlick and Looman 1984). Bowden (1960) determined that the chromosome number of rough fescue plants at other sites near Banff, Alberta, was $2n$ = 56, which is characteristic of *F. campestris* (F. altaica is reported with 2n=28). However, we observed some plants with characteristics of *F. altaica* but nevertheless best placed with *F. campestris*.

Data analysis

Mean cover (including zeros) for each species was calculated for each of the five, 10-quadrat transects for each grazing treatment. Frequency was the percentage of the 10 quadrats in a transect that contained that species. Covers and frequencies of each species were compared with a Proc T-test using the five transects as replicates. This test was generated with SAS software (SAS 2003*). The summary function of PC-Ord

TABLE 1. Mean cover and frequency of the more abundant (> 1% mean cover in either group) of 91 species in adjacent sections of prairie either grazed or non-grazed by Feral Horses (*Equus ferus caballus*), northern Kananaskis Country, Alberta.

Species	Cover (%)		Frequency (%)	
	Grazed	Non-grazed	Grazed	Non-grazed
Grasses and sedges				
Carex obtusata	4.14*	0.32*	76*	12*
Elymus lanceolatus	9.48*	3.06*	76*	30*
Festuca campestris	0.42*	30.26*	48*	98*
Koeleria macrantha	8.24*	1.78*	88*	48*
Muhlenbergia richardsonis	0.26*	3.36*	6*	26*
Poa secunda	5.32*	0.72*	84*	22*
Forbs				
Anemone multifida	0.16*	1.08*	8*	40*
Antennaria parvifolia	2.64*	0.26*	40*	8*
Artemisia frigida	3.34*	0.04*	56*	2*
Anticlea elegans	2.20*	0.066*	56*	28*
Campanula rotundifolia	2.28	1.14	52*	40*
Cerastium arvense	3.76*	1.90*	94*	60*
Comandra umbellata	1.40*	0.30*	36*	14*
Erigeron caespitosus	1.48*	0.16*	44*	6*
Galium boreale	3.98	4.36	90	82
Geum triflorum	0.06*	2.24*	22*	52*
Hedysarum boreale	0.84	1.26	2*	18*
Oxytropis monticola	4.60*	1.36*	68*	46*
Oxytropis sericea	2.62*	0.06*	58*	8*
Potentilla concinna	1.02	0.46	28	22
Primula conjugens	0.16*	1.00*	10*	42*
Pulsatilla patens	2.66*	0.98*	58	46
Toxicoscordion venenosus	1.92*	0.06*	52*	4*
Vicia americana	0.08*	1.94*	2*	40*
Shrubs				
Arctostaphylos uva-ursi	0.80*	14.84*	10*	42*
Dasiphora fruticosa	0.40*	1.82*	6	16
Juniperus horizontalis	15.46	14.46	46	52
Other				
Selaginella densa	7.54*	1.04*	68*	18*

*Significant difference between grazed and non-grazed sections ($P < 0.05$, Student's t test).

(McCune and Grace 2002*) was used to determine the two components of diversity (species richness and evenness) as well as two indices of diversity (Shannon-Wiener and Simpson's indexes) for each transect using mean species covers. The diversity variables were compared between grazing treatments (Proc T-TEST of SAS) using the results for the five transects as replicates.

Results

A total of 91 species were recorded in the 100 quadrats and 96 species (not including surrounding trees) were recorded in the entire prairie glade including the quadrats. The full species list is presented in Appendix I (along with authorities, common names and the accession numbers of voucher specimens at DAO). There were only five introduced species, and these were present in trace amounts.

The plant communities in grazed and non-grazed areas appeared different (Figure 1). The mean cover and mean frequency of species with a cover of at least 1% are listed in Table 1 by major group. There was considerable divergence in the species composition between the grazed and non-grazed sites. *Festuca campestris* and *Arctostaphylos uva-ursi* dominated the non-grazed site where covers were much greater than in the grazed site (30.26% versus 0.42% and 14.84% versus 0.8%, respectively). Other species with greater cover in the non-grazed areas included *Mulhenbergia richardsonis*, *Geum triflorum*, *Vicia americana*, and *Dasiphora fruiticosa*.

With grazing, the cover of many species increased. Among the graminoids, *Carex obstusata*, *Elymus lanceolatus* ssp. *lanceolatus*, *Koeleria macrantha*, and *Poa secunda ssp. secunda* increased. Among the forbs *Anemone patens* var. *multifida*, *Antennaria parvifolia*, *Anticlea elegans*, *Artemisia frigida*, *Cerastium arvense*, *Oxytropis monticola*, *O. sericea*, and *Toxicoscordion venosum var. venenosum* were more abundant in the grazed sites. *Selaginella densa* increased considerably with grazing. Several species including *Astragalus laxmannii* var. *robustior*, *Galium boreale*, *Potentilla concinna*, and *Juniperus horizontalis* had similar covers

FIGURE 1. Area in northern Kananaskis Country, Alberta, non-grazed by Horses (*Equus ferus caballus*) (left) showing clumps of *Festuca campestris* Rydberg and grazed area (right) showing more abundant wildflowers, including, in particular, the yellow-flowered species of *Oxytropis*, *O. monticola* and *O. sericea*). The blue-green colour of the prairie on the right is a result of more open-ground and pale plants such as *Artemisia frigida* and *Elymus lanceolatus*. Although still present as scattered culms, clumps of *Festuca campestris* are absent from the photo on the right. Photo by Paul M. Catling.

in both grazing treatments.

The mean number of species (species richness) did not differ between the grazing treatments (Table 2). Evenness was significantly greater with horse grazing. The Shannon-Wiener index indicated that feral horse grazing increased the species diversity of the plant community, whereas Simpson's index showed no effect.

TABLE 2. Effect of Feral Horse (*Equus ferus caballus*) grazing on mean diversity components determined from species covers in northern Kananaskis Country, Alberta.

	Grazed	Not grazed
Species number	44.6	48.8
Evenness	0.802*	0.685*
Shannon–Wiener index	3.041*	2.661*
Simpson's index	0.805	0.849

*Significant difference between grazed and not-grazed section ($P < 0.05$, Student's *t* test).

Discussion

Our list (Appendix 1) contains many species that have been observed in the various seral stages of the *F. campestris* grassland at the Stavely site in the Porcupine hills of southern Alberta (Willms *et al.* 1985). On the other hand, some species common in that grassland were either not present or were present in only trace amounts, including *Danthonia parryi* Scribner and *F. idahoensis* Elmer. Our site is at the northern limit of the former and beyond the northern limit of the latter (Packer 1994).

The low abundance of introduced species (5 of 94 in Appendix 1) suggests that, even with grazing, this is a relatively pristine plant community. Most important, only trace amounts of *Poa pratensis* L., one of the main species seen to increase with grazing at many *F. campestris* sites, were found here. Greater evenness with grazing reflects the great reduction in *F. campestris* and *Arctostaphylous uva-ursi* cover that favours a diversity of other species. Rough Fescue is known to be grazing sensitive (Willms *et al.* 1985), but why *A. uva-ursi* declines is not clear, as it is seldom grazed by horses. Trampling may be a factor.

Many of the species that increased with grazing have a more prostrate growth form and, thus, may partly avoid grazing. With grazing, four graminoids increased at the expense of *F. campestris*. The "increasers" did not include *Danthonia parryi*, which was the main increaser at the Stavely site (Willms *et al.* 1985). The cover of many of the lower growing forbs was also greater at the grazed site, including *Antennaria parvifolia*, *Anticlea elegans*, *Artemisia frigida*, *Cerastium arvense*, *Oxytropis* spp., and *Toxicoscordion venenosum* var. *venenosum*. Two palatable legumes (*Hedysarum boreale* and *Vicia americana*) increased with protection from grazing. Because of their high nutritive value, these are likely favoured by horses.

A short stature helps some species tolerate grazing, but makes them more susceptible to competition from robust grasses like *Festuca campestris*; thus, they would be expected to decline with protection from grazing. Competitive exclusion occurs when removal of disturbances, such as livestock grazing, allows a highly competitive species such as *F. campestris* to restrict the growth of other species through rapid canopy and root development, which limit both light and moisture availability, and litter accumulation, which reduces recruitment from tillers or seed (Grime 1973). The reduced evenness without horse grazing suggests that this had occurred to some extent. It might take longer for competitive exclusion to reduce the species number, or there may be sufficient grazing by wild ungulates in the "non-grazed" area to slow it. Studies of recovery of rough fescue grasslands (Willms *et al.* 1985; McLean and Tisdale 1972) show that, after several decades of recovery, species number was not reduced. However, in the longer term, *Festuca campestris* dominates to the exclusion of most other species (McLean and Tisdale 1972).

We found an increase in the Shannon-Wiener index with grazing, as shown by Bai *et al.* (2001) in Saskatchewan. Also similar to Bai *et al.*, we found no change in species richness with moderate grazing. The Simpson's index is less sensitive to the contribution of less-abundant species (DeJong 1975) and, thus, did not increase with grazing.

The results of this study correspond to those of many others (Trottier 1993; West 1993; McLaughlin and Mineau 1995) in suggesting some biodiversity benefits of moderate grazing. Studies of grazing effects at many sites throughout Alberta would determine whether grazing affects biodiversity in all grassland types. A study conducted in the mixed prairie (Willms *et al.* 2002) suggests that grazing does not always improve diversity.

General observations

The species of vascular plants that were much more abundant in grazed areas are known to increase with increased grazing pressure and are mostly not grasses. These species are likely those previously avoided by bison and currently avoided to some extent by feral horses. Both of these ungulates are grass specialists. Some of the plants that apparently increased with horse grazing are toxic to horses (e.g., *Oxytropis sericea* and *Toxicoscordion venenosum* var. *venenosum*; Majak *et al.* 2008) and were possibly avoided for this reason. Allowing only moderate grazing by horses may also be beneficial to the horses as they may avoid toxic plants while alternatives are available.

Both the area grazed by horses and the area free of horses were significant in terms of overall biodiversity, with different species present and different abundance values of shared species and high biodiversity values according to different indexes. The grazed area favoured wildflowers that serve pollinators including numerous bees and butterflies (most of the forbs listed in Table 1). The Greenish Blue butterfly (*Plebejus saepiolus amica* [W. H. Edwards, 1863]; Figure 2) was abundant in the grazed area, with up to 10 in view at any one time, but entirely absent from the non-grazed area. A population of Speckle-winged Rangeland Grasshoppers (*Arphia conspersa* Scudder, 1875), which prefer areas with bare soil (P. M. C. personal observation), was present in the grazed area but entirely absent from the adjacent non-grazed area. The dominance of clumped grasses in the horse-free area provided structural cover for nesting birds such as Vesper Sparrows (*Pooecetes gramineus*) that were absent in the grazed area. Other studies have shown that below-ground arthropods, scavenging arthropods, and grasshoppers increase with grazing (Laycock 1994) and that birds are variously adapted to the extent of the grazing (Knopf 1996). The differences in biodiversity between the two sections may be much greater for other groups than for vascular plants, further supporting the high biodiversity value of the presence of both grazing regimes.

Management implications

Based on studies of recovery from grazing in rough fescue communities (Willms *et al* 1985; McLean and Tisdale 1972), the non-grazed area is likely at a mid-seral stage. There may be a number of distinct biodiversity-rich intermediate stages of succession in foothills prairies based on different levels of grazing pressure and other factors. Biodiversity was not necessarily greatest at the apparent intermediate level of disturbance, as might be expected (Bai *et al.* 2001; Vujnovic *et al.* 2002). However, succession and disturbance levels may not provide the most informative view of prairies.

In pre-settlement times, prairies were likely a shifting mosaic of heterogeneous patches where fire and grazing played major roles, along with periodic drought (Fuhlendorf and Engle 2004). Other important factors affecting diversity may have been spatial and temporal variation in movements of wandering bison herds, and fluctuations in numbers of ungulate predators, as well as variation in their distributions. For example, bison traces would have been heavily grazed, but areas where predator risk was high would not have been grazed. Drought and fire would have influenced both of these factors. In the case of our study site, biodiversity was increased by the creation of two patches with different grazing regimes. An improvement in management would involve changing the patches over space and time by applying different ecological situations, especially using fire as well as grazing, as suggested by Fuhlendorf and Engle (2004). With the loss of free-

FIGURE 2. The Greenish Blue (*Plebejus saepiolus amica* (W.H. Edwards, 1863) was an abundant visitor to flowers of *Oxytropis* spp., which were much more abundant in the area of prairie subject to moderate grazing by feral Horses (*Equus ferus caballus*) than in an adjacent grazed area in northern Kananaskis Country, Alberta. Photo by Paul M. Catling.

ranging bison and the patch dynamics on which prairie diversity is based, the use of an increasing number of feral horses to achieve various levels of grazing is a potentially useful management tool that deserves widespread but well-planned application. Grazing by horses in foothills prairies at moderate to light levels can be beneficial in terms of biodiversity.

Acknowledgements

Bonnie Smith and C. C. Chinnappa of the University of Calgary Herbarium provided invaluable logistical support. Bow Valley Provincial Park warden, Rod Jaeger, and Chief Ecologist, Melanie Percy, provided information on the history of the study area and arranged for a permit to collect plant specimens. Gloria Cowley of Rafter Six guest ranch provided information on the history of the area west of the Kananaskis River.

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Received 21 January 2014
Accepted 8 May 2014

APPENDIX 1. Total list of species recorded (including quadrats) in a prairie glade in northern Kananaskis Country, Alberta, with scientific name, common name, some synonyms, and accession number of specimens preserved in the National Collection of Vascular Plants, Agriculture and Agri-Food Canada.

Scientific name	Common name	Accession number
Achillea millefolium L.	Common Yarrow	843223
Achnatherum richardsonii (Link) Barkworth	Richardson's Needlegrass	843236, 843298
Agoseris glauca (Pursh) Rafinesque	Pale Goat-chicory	843264
Allium cernuum Roth	Nodding Onion	843301
Androsace chamaejasme Wulfén ex Host	Sweet-flowered Rock Jasmine	843271
Androsace septentrionalis L.	Pygmyflower Rock jasmine	843228
Anemone multifida Poiret	Red Windflower	843221
Anemone patens L. var. *multifida* Pritzel (syn. *Pulsatilla patens*)	Prairie Crocus	843267
Antennaria anaphaloides Rydberg	Tall Pussytoes	843296
Antennaria parvifolia Nuttall	Little-leaved Pussytoes	843319
Anticlea elegans (Pursh) Rydberg (syn. *Zigadenus elegans*)	Mountain Death Camas	843320
Arabis hirsuta M. Hopkins var. *pycnocarpa* (M. Hopkins) Rollins	Hairy Rockcress	843250
Arctostaphylos uva-ursi (L.) Sprengel	Red Bearberry	
Artemisia campestris L.	Pacific Wormwood	843315
Artemisia frigida Willdenow	Prairie Sagebrush	843316
Astragalus agrestis Douglas ex G. Don	Cock's-head	843278
Astragalus australis (L.) Lamarck	Indian Milk-vetch	843286, 843298
Astragalus laxmanii Jacquin var. *robustior* (Hooker) Barneby and S.L. Welsh	Ascending Purple Milk-vetch	
**Bromus inermis* Leysser	Smooth Brome	
Campanula rotundifolia L.	Round-leaf Harebell	
Carex duriuscula C. A. Meyer	Spikerush Sedge	843252
Carex filifolia Nuttall	Thread-leaved Sedge	843238, 843275
Carex obtusata Liljeblad	Blunt Sedge	843277
Carex richardsonii R. Brown	Richardson's Sedge	843302
Carex rossii Boott	Ross' Sedge	843240, 843260
Carex scirpoidea Michaux	Canadian Single-spike Sedge	843272
Castilleja rhexifolia Rydberg	Rosy Indian-paintbrush	843297
Cerastium arvense L.	Field Mouse-ear Chickweed	843262
Comandra umbellata (L.) Nuttall ssp. *pallida* (A. de Candolle) Piehl	Pale Bastard-toadflax	843279
Crepis runcinata (E. James) Torrey & A. Gray	Fiddle-leaved Hawksbeard	843306
Dactylorhiza viridis (L.) R.M. Bateman, Pridgeon & M.W. Chase (syn. *Coeloglossum viride* var. *virescens*)	Frog Orchid	843314
Dasiphora fruticosa (L.) Rydberg (syn. *Dasiphora fruticosa* ssp. *floribunda* (Pursh) Kartesz)	Shrubby Cinquefoil	843239
Delphinium bicolor Nuttall	Flathead Larkspur	843219
Draba cana Rydberg (syn. *Draba breweri* var. *cana*)	Cushion Whitlowgrass	843292, 843318
Draba nemorosa L.	Woodland Whitlowgrass	843253, 843323
Elymus glaucus Buckley	Blue Wildrye	843237
Elymus lanceolatus (Scribner & J.G. Smith) Gould ssp. *lanceolatus*	Streamside Wildrye	843243
Erigeron caespitosus Nuttall	Tufted Fleabane	843224
Erigeron glabellus Nuttall var. *glabellus* (syn. *Erigeron asper* Nuttall)	Rough Fleabane	843220
Eriogonum flavum Nuttall	Alpine Golden Wild Buckwheat	843300
Erysimum inconspicuum (S. Watson) MacMillan	Shy Wallflower	843258
Festuca campestris Rydberg	Northern Rough Fescue	843231, 843273
**Festuca* cf. *ovina* L.	Sheep Fescue	843291, 843295
Festuca saximontana Rydberg var. *purpusiana* (Saint-Yves) Frederiksen & Pavlick	Rocky Mountain Fescue	843241, 843313, 843324
Fragaria virginiana Miller	Wild Strawberry	
Gaillardia aristata Pursh	Great Blanketflower	843288, 843310
Galium boreale L.	Northern Bedstraw	
Geum triflorum Pursh	Prairie Smoke	843255
Hedysarum alpinum L. (syn *Hedysarum alpinum* ssp. *americanum* (Michaux ex Pursh) B. Fedtschenko)	Alpine Sweet-vetch	843225, 843268, 843304
Gentianella amarella (L.) Börner	Autumn Dwarf Gentian	843256

APPENDIX 1. *(continued)*

Scientific name	Common name	Accession number
Hedysarum boreale Nuttall	Northern Hedysarum	
Hedysarum sulphurescens Rydberg	Yellow Sweet-vetch	843227
Helictotrichon hookeri (Scribner) Holub	Hooker's Alpine Oatgrass	843230, 843232, 843299, 843311, 843321
Heuchera cylindrica Douglas	Poker Alumroot	843274
Juniperus communis var. *depressa* Pursh	Common Juniper	
Juniperus horizontalis Moench	Creeping Juniper	
Koeleria macrantha (Ledebour) Schultes	Junegrass	843234, 843261
**Lappula squarrosa* (Retzius) Dumortier	Bristly Sheepburr	843218
Lilium philadelphicum L. (syn. *Lilium philadelphicum* var. *andinum* (Nuttall) Ker Gawler)	Wood Lily	843293
Lithospermum ruderale Douglas ex Lehmann	Columbia Puccoon	843308
Maianthemum stellatum (L.) Link	Starry False Solomon's Seal	
Muhlenbergia richardsonis (Trinius) Rydberg	Mat Muhly	843354
Oxytropis borealis de Candolle *var. viscida* (Nuttall) S.L. Welsh	Boreal Locoweed	843305
Oxytropis deflexa (Pallas) de Candolle ssp. *sericea* (Torrey & A. Gray) Cody (syn. *Oxytropis deflexa* var. *sericea* Torrey & A. Gray)	White Pendant-pod Locoweed	843222, 843247
Oxytropis monticola A. Gray	Yellow-flower Locoweed	843249, 843276, 843282, 843283
Oxytropis sericea Nuttall	Rocky Mountain Locoweed	843248, 843280
Oxytropis splendens Douglas ex Hooker	Whorled Locoweed	
Packera cana (Hooker) W.A Weber & Á. Löve	Silvery Groundsel	843287
Penstemon confertus Douglas ex Lindley	Lesser Yellow Beardtongue	843294
**Phleum pratense* L.	Common Timothy	
Poa cusickii Vasey	Cusick's Bluegrass	843254, 843303
Poa pratensis L.	Kentucky Bluegrass	843269
Poa secunda J. Presl ssp. *secunda* (syn. *Poa sandbergii* Vasey)	Sandberg's Bluegrass	843233, 843235, 843246, 843281
Poa sp.	Bluegrass (unknown)	843322
Populus tremuloides Michaux	Trembling Aspen	
Potentilla concinna Richardson	Red Cinquefoil	843244
Potentilla pensylvanica L.	Pennsylvania Cinquefoil	843245
Primula conjugens (Greene) A.R. Mast & Reveal var. *conjugens* (syn. *Dodecatheon conjugens*)	Bonneville Shootingstar	843290
Primula pauciflora (Greene) A.R. Mast & Reveal var. *pauciflora (*syn. *Dodecatheon pulchellum*)	Dark-throat Shootingstar	843298
Rhinanthus minor L.	Little Yellow Rattle	
Sabulina rubella (Wahlenberg) Dillenberger & Kadereit (syn. *Minuartia rubella*)	Boreal Stitchwort	843259
Selaginella densa Rydberg	Dense Spikemoss	843242
Silene parryi (S. Watson) C.L. Hitchcock & Maguire	Parry's Catchfly	843317
Sisyrinchium montanum Greene	Strict Blue-eyed Grass	843251
Sisyrinchium septentrionale E.P. Bicknell	Northern Blue-eyed Grass	843257
Solidago simplex ssp.	Mt. Albert Goldenrod	
Symphoricarpos sp.	Snowberry	843309
Symphyotrichum laeve (L.) A. Löve & D. Löve var. *geyeri* (A. Gray) G.L. Nesom	Smooth Blue Aster	
**Taraxacum officinale* F.W. Wiggers	Common Dandelion	843226
Thalictrum venulosum Trelease	Veiny-leaved Meadow-rue	843263
Toxicoscordion venenosum (S. Watson) Rydberg var. *venensoum*	Meadow Death Camas	843265, 843312
Vicia americana Muhlenberg ex Willdenow	American Purple Vetch	843229
Viola canadensis L.,	Canada Violet	
Zizia aptera (A. Gray) Fernald	Heart-leaved Alexanders	843266

*Non-native species.

The Flora of Cunningham Inlet, Somerset Island, Nunavut: History, Analysis, and New Collections of Vascular Plants, Mosses, Lichens, and Algae

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Sokoloff, Paul C. 2015. The flora of Cunningham Inlet, Somerset Island, Nunavut: history, analysis, and new collections of vascular plants, mosses, lichens, and algae. Canadian Field-Naturalist 129(1): 24–37.

New collections of vascular plants, bryophytes, lichen, and algae are reported for Cunningham Inlet on the north coast of Somerset Island, Nunavut. This list of 48 species of vascular plants, 13 bryophytes, 10 lichens, and five algae includes 136 specimens collected in 2013 and 39 previously unreported specimens from the National Herbarium of Canada at the Canadian Museum of Nature (CAN), Agriculture and Agri-Food Canada's Vascular Plant Herbarium (DAO), and University of Alberta (ALTA). Ten vascular plants from previous collecting in 1958 are re-reported here to give a comprehensive account of the vascular plant flora of the region. Two vascular plants are recorded for the first time for Somerset Island: Smooth Draba (*Draba glabella* Pursh) and Edlund's Fescue (*Festuca edlundiae* S. G. Aiken, Consaul & Lefkovitch).

Key Words: Arctic; Nunavut; Somerset Island; Cunningham Inlet; vascular plants; *Festuca edlundiae*; *Draba glabella*

Introduction

Located on the northern coast of Somerset Island, Nunavut, Cunningham Inlet is a focal point of marine mammal research as thousands of Beluga Whales (*Delphinapterus leucas*) enter it each summer (Smith and Sjare 1990; Smith and Martin 1994). Because of this remarkable natural phenomenon, Arctic Watch Lodge was established on the inlet as a destination for wilderness tourism. Although this remote area receives numerous visitors and the inlet is close to Canada's high Arctic research hub in Resolute (79 km away), only limited botanical research has previously been carried out at Cunningham Inlet. As a result, relatively few species of vascular plants, mosses, lichens, and algae are reported from the inlet. This might be because of the relative lack of plant diversity on the northern shore of Somerset Island; the Circumpolar Arctic Vegetation Map team classifies this site as cryptogam–herb barren: sparse barren landscapes with little vegetation cover (Walker *et al.* 2005).

The first significant collecting activity on Somerset Island occurred in 1958, when D. B. O. Savile (Agriculture Canada) collected vascular plants, mosses, and fungi from 12 sites around the perimeter of the island (Savile 1959). Before this, only sporadic collections had been made, many of which are reported by Polunin (1940). Savile visited Cunningham Inlet very briefly on 11 August 1958, and "selective collecting was done, principally of parasitic fungi" (Savile 1959). He collected 11 vascular plants (10 species) and three fungi and deposited them at Agriculture and Agri-Food Canada's, Vascular Plant Herbarium (DAO) and National Mycological Herbarium (DAOM). These collections were reported in Savile (1959), and a subset was mapped for *Flora of the Canadian Arctic Archipelago* (Aiken *et al.* 2007). These specimens may have also been mapped by Porsild and Cody (1980), but they are difficult to distinguish among the individual dots that cover nearly the entirety of Somerset Island on their location maps.

Before Savile's work, only one known specimen had been collected from Cunningham Inlet: a single sheet of Arctic False Wallflower (*Parrya arctica* R. Brown) collected by B. Shindman during "Operation Magnetic" in 1949.

Over a decade passed until the next collector, L. C. Bliss of the University of Alberta, visited Cunningham Inlet to study the plant communities in polar desert habitats (Bliss *et al.* 1984). His 23 previously unreported specimens (19 vascular plant species) are deposited at the University of Alberta herbarium (ALTA).

Steven V. Zoltai and V. Woo conducted extensive soil and vegetation reconnaissance on Somerset Island for a proposed gas pipeline through the Canadian Arctic in 1977 (Woo and Zoltai 1977). While they used field identifications from plots and transects to characterize the vegetation of habitats sampled, voucher specimens were taken and sent to Agriculture Canada (DAO), including three species of Poaceae from the vicinity of Cunningham Inlet.

More recently, on 13 July 2004, L. Consaul and A. Archambault of the Canadian Museum of Nature made a brief stop at Cunningham Inlet and collected 11 previously unreported specimens for the National Herbarium of Canada (CAN), focusing primarily on False Wallflowers (*Parrya* R. Brown) and Alkaligrasses (*Puccinellia* Parlatore). In total, they collected four vascular plant species.

In July 2013, I embarked on a 6-day plant collecting trip to Cunningham Inlet as a scientist-in-residence for Arctic Watch Lodge's 2013 Steve Amarualik Youth Leadership Expedition, a program designed to bring out leadership potential and teach outdoor skills to youth from the south and the north. The collections from this trip are described here alongside the collections made on the four previously mentioned trips. This provides a comprehensive overview of the vascular plant flora on the inlet, which consists of 48 species and 31 genera in 11 plant families. I include two vascular plant species previously not known to occur on Somerset Island. In addition, I report here the first substantial inventory of cryptogams and marine algae from Cunningham Inlet.

Study Area

From 6 to 12 July 2013, I collected vascular plants, lichens, mosses, algae, and fungi in the vicinity of Cunningham Inlet (74°04'N, 93°48'W; Figure 1).

Methods

I collected specimens of all vascular plant and marine algae species encountered and opportunistically collected mosses, lichens, and fungi (Figure 2). Two students, Zachary Halem (New York, New York, USA) and Alicia Manik (Resolute, Nunavut, Canada), provided extensive assistance with the collection and found additional specimens; thus they are named as collectors where appropriate. In all, 136 numbers were collected: 93 vascular plants (11 families, 31 genera, and 48 species), 12 bryophytes (eight families, 13 genera, and 13 species), 16 marine algae and terrestrial cyanobacteria (five families, five genera, and five species), 12 lichens (seven families, 10 genera, and 10 species), and two fungi. All specimens have been deposited in the relevant collection (CAN for vascular plants, CANM for bryophytes, CANL for lichens, and CANA for algae) in the National Herbarium of Canada at the Canadian Museum of Nature, except the fungal collections, which were deposited at DAOM. Herbaria with duplicate specimens are indicated in the species accounts by their herbarium acronym. Twelve unidentified vascular plant, lichen, algae, and fungal specimens collected during the trip are not treated in this paper: *Sokoloff 149, 159, 162, 177, 179, 194, 195, 196, 208, 222, 229*, and *241*.

I also examined and verified the vascular plant collections made by Savile (11 numbers), Bliss (24 num-

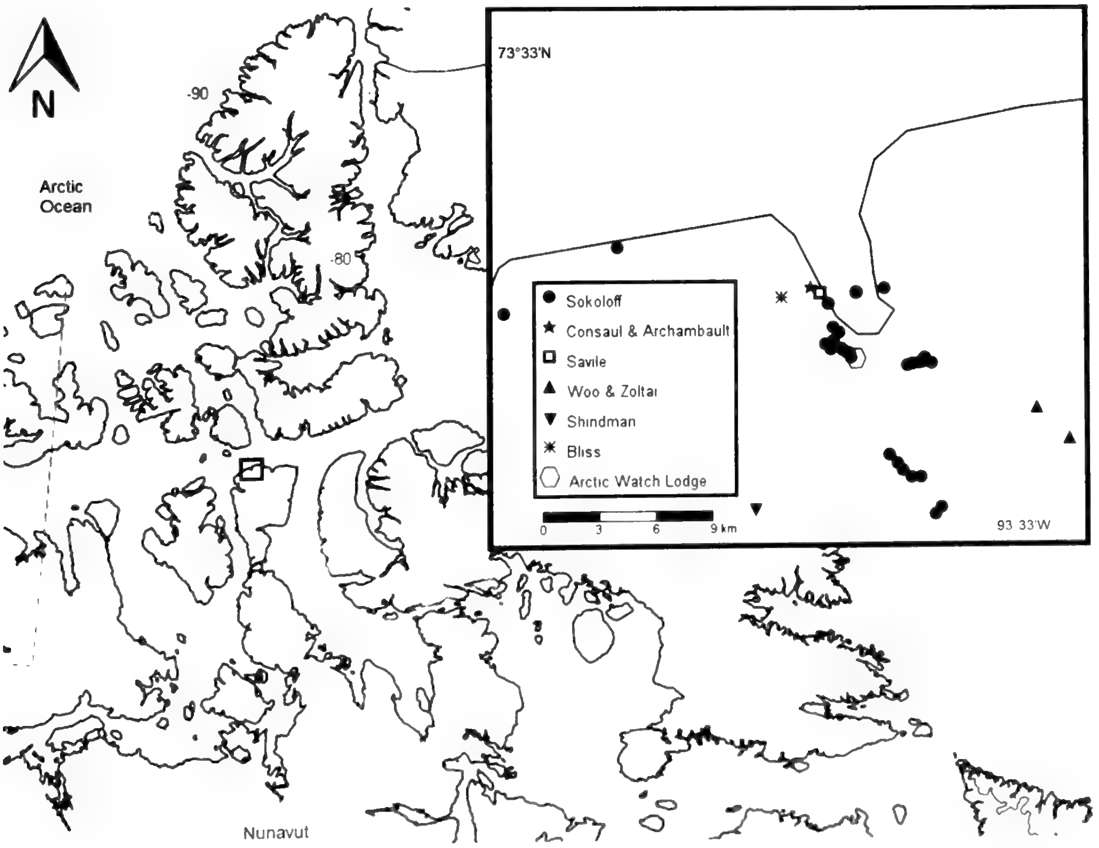

FIGURE 1: Locations of vascular plant, algae, fungi, and bryophyte collections made in the Cunningham Inlet area, Somerset Island, Nunavut. Locations of earlier collections (Sokoloff, Consaul & Archambault, Savile, Woo & Zoltai, Shindman, and Bliss) and Arctic Watch Lodge are denoted by symbols (right inset). There is a peninsula on the northeast corner of Cunningham Inlet not shown due to map resolution.

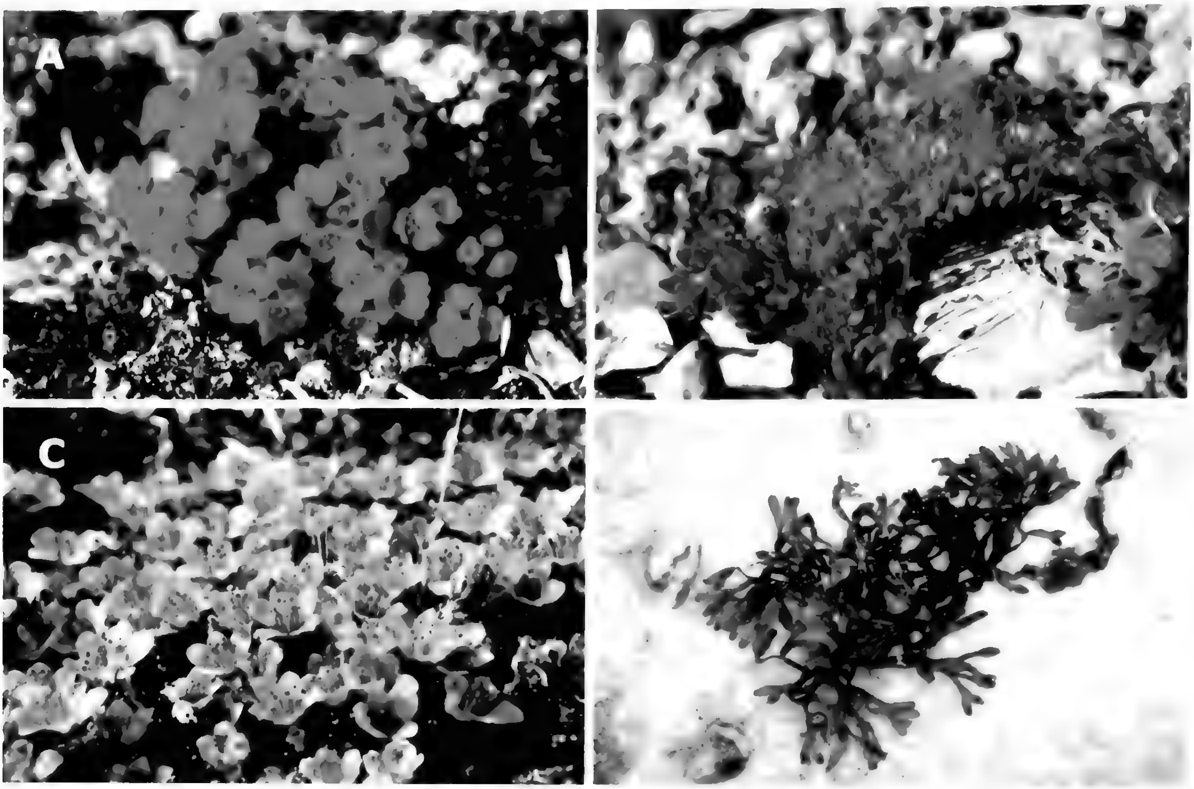

FIGURE 2: Diverse specimens from the Cunningham Inlet area, Somerset Island, Nunavut: A) Flat-top Draba (*Draba corymbosa* R. Brown ex de Candolle), *Sokoloff 245*; B) *Ptychostomum wrightii*, *Sokoloff 187*, C) Purple Mountain Saxifrage (*Saxifraga oppositifolia* L.), *Sokoloff 181*, D) *Fucus distichus*, *Sokoloff 140*. Photos by P. Sokoloff.

bers), Woo and Zoltai (3 numbers), Shindman (1 number), and Consaul and Archambault (11 numbers) and report all except Savile's for the first time. Some material was examined and identified by specialists, who are listed in the acknowledgements.

The species accounts are organized alphabetically by family, genus, and species within each major group collected: algae, bryophytes, lichens, and vascular plants. Common names for vascular plant species in English and French are taken from Vascan (Brouillet *et al.* 2010*). Inuktitut names are taken from the *Common Plants of Nunavut* (Mallory and Aiken 2004). Collections were plotted using SimpleMappr (open-source software, David P. Shorthouse, http://www.simplemappr.net) (Figure 1). Species distributions are taken from the Annotated Checklist of the Panarctic Flora (Elven *et al.* 2011*).

Results

Diversity in the algae, bryophyte, and lichen collections was relatively low, and the opportunistic sampling strategy makes it difficult to compare our collections with known checklists from the area. Five species of algae were documented, in five genera representing five families (not including unidentified samples). For bryophytes, 14 genera and species from eight families were collected, and 10 species and genera from seven families of lichens were documented.

For vascular plants, 48 species in 31 genera and 11 families were documented for Cunningham Inlet. This accounts for nearly half of the 98 species recorded for Somerset Island by Savile (1959) and the 75 species recorded by Woo and Zoltai (1959) and represents 40% of the 119 species documented for the Island in *Flora of the Canadian Arctic Archipelago* (Aiken *et al.* 2007, data obtained from species maps). At Cunningham Inlet, Poaceae, Brassicaceae, and Caryophyllaceae were the most species-rich families, accounting for 25%, 23%, and 15% of the species collected. The majority of vascular plants documented (65%) possess a circumpolar distribution pattern; others are amphi-Beringian and North American species.

Description of specimens

ALGAE

Alariaceae

Alaria esculenta (L.) Greville – NUNAVUT: Somerset Island, in sea ice in centre of Cunningham Inlet, 3 km north of Arctic Watch Lodge, thick sea ice with algae embedded, 74°5'54"N, 93°47'15"W, 0 m, 10 July 2013, *P. Sokoloff 192* (CANA 93578).

Costariaceae

Agarum cribrosum Bory de Saint-Vincent – NUNAVUT: Somerset Island, on tidal flats on west edge of Cunningham Inlet, 1.5 km north of Arctic Watch

Lodge, in rocky tidal zone, mostly bare stones, with *Fucus distichus*, 74°4'48.7"N, 93°49'27.7"W, 53 m, 8 July 2013, *P. Sokoloff 139* (CANA 93579); sea ice in centre of Cunningham Inlet, 3 km north of Arctic Watch Lodge, thick sea ice with algae embedded, 74°5'54"N, 93°47'15"W, 0 m, 10 July 2013, *P. Sokoloff 193* (CANA 93580).

Fucaceae

Fucus distichus L. – NUNAVUT: Somerset Island, tidal flats on west edge of Cunningham Inlet, 1.5 km north of Arctic Watch Lodge, rocky tidal zone, mostly bare stones, 74°4'48.7"N, 93°49'27.7"W, 53 m, 8 July 2013, *P. Sokoloff 140* (CANA 93581); tidal flats on west edge of Cunningham Inlet, 1.5 km north of Arctic Watch Lodge, rocky tidal zone, mostly bare stones, 74°4'48.7"N, 93°49'27.7"W, 53 m, 8 July 2013, *P. Sokoloff 141* (CANA 93582); tidal flats on west edge of Cunningham Inlet, 1.5 km north of Arctic Watch Lodge, rocky tidal zone, mostly bare stones, 74°4'48.7"N, 93°49'27.7"W, 53 m, 8 July 2013, *P. Sokoloff 142* (CANA 93583); tidal flats on west edge of Cunningham Inlet, 1.5 km north of Arctic Watch Lodge, rocky tidal zone, mostly bare stones, 74°4'48.7"N, 93°49'27.7"W, 53 m, 8 July 2013, *P. Sokoloff 143a* (CANA 93584); sea ice in centre of Cunningham Inlet, 3 km north of Arctic Watch Lodge, thick sea ice with algae embedded, 74°5'54"N, 93°47'15"W, 0 m, 10 July 2013, *P. Sokoloff 191* (CANA 93585).

Laminariaceae

Saccharina latissima (L.) C.E. Lane, C. Mayes, Druehl & G.W. Saunders – NUNAVUT: Somerset Island, sea ice in centre of Cunningham Inlet, 3 km north of Arctic Watch Lodge, thick sea ice with algae embedded, 74°5'54"N, 93°47'15"W, 0 m, 10 July 2013, *P. Sokoloff 190* (CANA 93586).

Nostocaceae

Nostoc commune Vaucher ex Bornet & Flahault – NUNAVUT: Somerset Island, north-facing ridge west of Arctic Watch Lodge, *Eriophorum–Calamagrostis* meadow, 74°4'27.7"N, 93°50'39.4"W, 118 m, 9 July 2013, *P. Sokoloff 175* (CANA 93588); north-facing ridge west of Arctic Watch Lodge, *Eriophorum–Calamagrostis* meadow, 74°4'27.7"N, 93°50'39.4"W, 118 m, 9 July 2013, *P. Sokoloff 176* (CANA 93587).

BRYOPHYTES

Amblystegiaceae

Campylium stellatum (Hedwig) Christian Erasmus Otterstrøm Jensen – NUNAVUT: Somerset Island, 2 km south of point at Cape Anne, muddy wet ground in marshy field alongside river, with *Saxifraga oppositifolia, Salix arctica, Dryas integrifolia*, 74°6'23.3"N, 94°23'44.25"W, 26 m, 10 July 2013, *P. Sokoloff, Z. Halem 239 (associated species in same packet as Ditrichum flexicaule)* (CANM 332657).

Scorpidium revolvens (O.P. Swartz ex Anonymo) W.V. Rubers in A. Touw & W.V. Rubers – NUNAVUT: Somerset Island, wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, wet mossy tundra, with *Eriophorum angustifolium*, 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 184* (CANM 332651).

Drepanocladus sordidus (Müller Hal.) Hedenäs NUNAVUT: Somerset Island, south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 220* (CANM 332655); slope above alluvial plain of Cunningham River, 4 km east of Arctic Watch Lodge, mossy bank in wet sedge meadow, 74°3'40.7"N, 93°41'32.2"W, 40 m, 7 July 2013, *P. Sokoloff 124 (associated species in same packet as Brachythecium cirrosum)* (CANM 332646).

Hygrohypnum luridum (Hedwig) Jennings - NUNAVUT: Somerset Island, Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet seepy rocks at edge of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 204* (CANM 332653).

Brachytheciaceae

Brachythecium cirrosum (Schwägrichen) Schimper – NUNAVUT: Somerset Island, slope above alluvial plain of Cunningham River, 4 km east of Arctic Watch Lodge, mossy bank in wet sedge meadow, 74°3'40.7"N, 93°41'32.2"W, 40 m, 7 July 2013, *P. Sokoloff 124* (CANM 332646).

Bryaceae

Ptychostomum wrightii (Sullivant) J.R. Spence – NUNAVUT: Somerset Island, garden spot below sewage lagoon at Arctic Watch Lodge, lush green patch in rocky scree, with *Salix arctica, Saxifraga oppositifolia, Papaver* sp., *Parrya arctica*, 74°4'13.1"N, 93°48'55.8"W, 16 m, 9 July 2013, *P. Sokoloff 187* (CANM 332652); south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 221* (CANM 332656).

Ditrichaceae

Distichium capillaceum (Hedwig) Bruch & Schimper – NUNAVUT: Somerset Island, confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 147 (associated species in same packet as Ditrichum flexicaule)* (CANM 332649).

Ditrichum flexicaule (Schwägrichen) Hampe NUNAVUT: Somerset Island, sloping west wall at Gull Canyon over dry creek bed, 4 km east of Arctic Watch Lodge, wet mossy slope, with *Saxifraga oppositifolia, Cerastium arcticum, Draba glabella*, 74°3'37.5"N, 93°40'17.7"W, 40 m, 7 July 2013, *P. Sokoloff 132* (CANM 332647); confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, with *Cerastium alpinum*, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 147*

(CANM 332649); 2 km south of point at Cape Anne, muddy wet ground in marshy field alongside river, with *Saxifraga oppositifolia, Salix arctica, Dryas integrifolia*, 74°6'23.3"N, 94°23'44.25"W, 26 m, 10 July 2013, *P. Sokoloff, Z. Halem 239 (associated species in same packet as Orthothecium chryseum)* (CANM 332657).

Grimmiaceae

Schistidium rivulare (Bridel) Podpera – NUNAVUT: Somerset Island, Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, dry rocks at edge of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 205* (CANM 332654).

Hypnaceae

Orthothecium chryseum (Schwägrichen in Schultes) Schimper in Bruch & Schimper – NUNAVUT: Somerset Island, 2 km south of point at Cape Anne, muddy wet ground in marshy field alongside river, with *Saxifraga oppositifolia, Salix arctica, Dryas integrifolia*, 74°6'23.3"N, 94°23'44.25"W, 26 m, 10 July 2013, *P. Sokoloff, Z. Halem 239* (CANM 332657); slope above alluvial plain of Cunningham River, 4 km east of Arctic Watch Lodge, mossy bank in wet sedge meadow, 74°3'40.7"N, 93°41'32.2"W, 40 m, 7 July 2013, *P. Sokoloff 124 (associated species in same packet as Brachythecium cirrosum)* (CANM 332646).

Mniaceae

Cinclidium cf. *arcticum* (Bruch & Schimper) Schimper – NUNAVUT: Somerset Island, 2 km south of point at Cape Anne, muddy wet ground in marshy field alongside river, with *Saxifraga oppositifolia, Salix arctica, Dryas integrifolia*, 74°6'23.3"N, 94°23'44.25"W, 26 m, 10 July 2013, *P. Sokoloff, Z. Halem 239 (associated species in same packet as Orthothecium chryseum)* (CANM 332657).

Mnium blyttii Bruch & Schimper – NUNAVUT: Somerset Island, eastern edge of Gull Canyon, 4 km east of Arctic Watch Lodge, extremely deep moss directly above snow line, 74°3'48.4"N, 93°40'57.2"W, 40 m, 7 July 2013, *P. Sokoloff 137* (CANM 332648).

Scorpidiaceae

Sanionia uncinata (Hedwig) Loeske – NUNAVUT: Somerset Island, western edge of Gull Canyon, 4 km east of Arctic Watch Lodge, extremely deep moss directly above snow line, 74°3'48.4"N, 93°40'57.2"W, 40 m, 7 July 2013, *P. Sokoloff 137 (associated species in same packet as Mnium blyttii)* (CANM 332648).

LICHENS

Icmadophilaceae

Thamnolia subuliformis (Ehrhart) W.L. Culberson – NUNAVUT: Somerset Island, mossy wet area outside whale biologist's cabin, 1.5 km north of Arctic Watch Lodge, wet mossy rocks, 74°4'58.8"N, 93°50'2"W, 94 m, 8 July 2013, *P. Sokoloff 157* (CANL 125971).

Lecanoraceae

Lecidella patavina (A. Massalongo) Knoph & Leuckert – NUNAVUT: Somerset Island, rocky beach on west coast of Cunningham Inlet, directly across from Flat Rock Falls 4 km north of Arctic Watch Lodge, barren rocks, 74°5'40"N, 93°50'16"W, 5 m, 10 July 2013, *P. Sokoloff 211* (CANL 125978).

Megasporaceae

Aspicilia candida (Anzi) Hue – NUNAVUT: Somerset Island, Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, dry gravel scree above falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff, R. Weber 206* (CANL 125980).

Megaspora verrucosa (Acharius) Hafellner & V. Wirth – NUNAVUT: Somerset Island, mossy wet area outside whale biologist's cabin, 1.5 km north of Arctic Watch Lodge, wet mossy rocks, with *Saxifraga cernua, Luzula confusa, Draba* sp., *Salix arctica*, 74°4'58.8"N, 93°50'2"W, 94 m, 8 July 2013, *P. Sokoloff 160* (CANL 125974); mossy wet area outside whale biologist's cabin, 1.5 km north of Arctic Watch Lodge, wet mossy rocks, with *Saxifraga cernua, Luzula confusa, Draba* sp., *Salix arctica*, 74°4'58.8"N, 93°50'2"W, 94 m, 8 July 2013, *P. Sokoloff 163* (CANL 125976).

Parmeliaceae

Allocetraria madreporiformis (Withering) Kärnefelt & A. Thell – NUNAVUT: Somerset Island, mossy wet area outside whale biologist's cabin, 1.5 km north of Arctic Watch Lodge, wet mossy rocks, with *Saxifraga cernua, Luzula confusa, Draba* sp., *Salix arctica*, 74°4'58.8"N, 93°50'2"W, 94 m, 8 July 2013, *P. Sokoloff 158* (CANL 125972).

Evernia divaricata (L.) Acharius – NUNAVUT: Somerset Island, windswept dry rocks on ridge off northwest coast of Cunningham Inlet, dry rocky talus, with *Saxifraga oppositifolia*, 74°4'35.3"N, 93°50'7.9"W, 98 m, 9 July 2013, *P. Sokoloff 186* (CANL 125977).

Vulpicida tilesii (Acharius) J.-E. Mattsson & M.J. Lai – NUNAVUT: Somerset Island, west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, dry rocky scree, with *Festuca* sp., *Saxifraga oppositifolia*, 74°3'42.4"N, 93°40'47.8"W, 50 m, 7 July 2013, *P. Sokoloff 129* (CANL 125969).

Peltigeraceae

Peltigera ponojensis Gyelnik – NUNAVUT: Somerset Island, south end of Sunday Lake, 6 km south of Arctic Watch Lodge, mossy knoll in wet tundra, 74°1'7.8"N, 93°45'41.5"W, 66 m, 11 July 2013, *P. Sokoloff 214* (CANL 125979).

Physciaceae

Physcia dubia (Hoffmann) Lettau – NUNAVUT: Somerset Island, west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, dry rocky scree, with *Festuca* sp., *Saxifraga oppositifolia*, 74°3'42.4"N, 93°40'47.8"W, 50 m, 7 July 2013, *P. Sokoloff 130* (CANL 125970).

Teloschistaceae

Xanthoria elegans (Link) Th. Fries – NUNAVUT: Somerset Island, mossy wet area outside whale biologist's cabin, 1.5 km north of Arctic Watch Lodge, wet mossy rocks, with *Saxifraga cernua, Luzula confusa, Draba* sp., *Salix arctica*, 74°4'58.8"N, 93°50'2"W, 94 m, 8 July 2013, *P. Sokoloff 161* (CANL 125975).

Vascular Plants

Brassicaceae

Braya glabella Richardson ssp. *purpurascens* (R. Brown) W.J. Cody (Purple Braya, braya purpurine, Airaujuit) [circumpolar-cordilleran] – NUNAVUT: Somerset Island, on a mild slope, with *Dryas integrifolia, Salix*, 74°6'00"N, 93°51'00"W, 63 m, July 13, 2004, *A. Archambault & L. Consaul aa53* (CAN 603400); west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, tundra in dry mud, with *Dryas integrifolia*, 74°3'41.1"N, 93°41'18.8"W, 50 m, 7 July 2013, *P. Sokoloff 125* (CAN 603292).

Cardamine bellidifolia L. (Alpine Bittercress, cardamine à feuilles de pâquerette) [circumpolar-alpine] – NUNAVUT: Somerset Island, Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 197* (CAN 603293); south end of Sunday Lake, north of Cunningham River, 7 km south of Arctic Watch Lodge, mud flats, 74°0'23.3"N, 93°42'43.5"W, 41 m, 11 July 2013, *P. Sokoloff 230* (CAN 603294).

Cochlearia groenlandica L. (Greenland Scurvygrass, cranson du Groenland, Tipitsiariktut nunarait) [circumpolar] – NUNAVUT: Somerset Island, south end of Sunday Lake, north of Cunningham River, 7 km south of Arctic Watch Lodge, mud flats, 74°0'23.3"N, 93°42'43.5"W, 41 m, 11 July 2013, *P. Sokoloff 233* (CAN 603295).

Draba corymbosa R. Brown ex de Candolle (Flattop Draba, drave en corymbe) [circumpolar] – Cunningham Inlet, 8 km from inlet, uplands, polar desert, Somerset plateau, 74°06'N, 93°55'W, 250 m, 20 July 1976, *L.C. Bliss s.n.* (ALTA 56724); Cunningham Inlet, 8 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 225 m, 20 July 1976, *L.C. Bliss s.n.* (ALTA 56723); dry stone ridge immediately west of Arctic Watch Lodge, in gravel scree, dry gravel, with *Saxifraga oppositifolia, Salix arctica, Papaver* sp., 74°4'20.2"N, 93°49'22.6"W, 20 m, 6 July 2013, *P. Sokoloff 112* (CAN 603296); western cliff wall of Gull Canyon, below gull nesting area, wet rocks directly under water seeps and waterfall, dense lush vegetation, with *Saxifraga cespitosa, Bistorta vivipara, Saxifraga cernua*, bryophytes, 74°3'48.4"N, 93°40'57.2"W, 40 m, 7 July 2013, *P. Sokoloff 135* (CAN 603297); west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, dry rocky scree, with *Xanthoria elegans, Festuca* sp., *Saxifraga oppositifolia*, 74°3'42.4"N, 93°40'47.8"W, 50 m, 7 July 2013, *P. Sokoloff 138* (CAN 603298); gravelly scree ledge above Cunningham River, directly adjacent to Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 8 July 2013, *P. Sokoloff 151* (CAN 603299); north-facing slope west of Arctic Watch Lodge, wet rocky seep in *Dryas Eriophorum* tundra, with *Dryas integrifolia, Salix arctica, Draba corymbosa, Cerastium arcticum*, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 165* (CAN 603300); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet *Dryas* tundra with snow-bed community, with *Saxifraga oppositifolia, Salix arctica*, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 210* (CAN 603301); gravelly scree ledge above Cunningham River, 9 km southeast of Arctic Watch Lodge, dry gravel and barren rocks, 73°59'27.3"N, 93°40'57.5"W, 69 m, 11 July 2013, *P. Sokoloff 234* (CAN 603302); garden spot below sewage lagoon at Arctic Watch Lodge, lush green patch in rocky scree, with *Salix arctica, Saxifraga oppositifolia, Papaver* sp., *Parrya arctica*, bryophytes, 74°4'13.1"N, 93°48'55.8"W, 16 m, 12 July 2013, *P. Sokoloff, A. Manik 245* (CAN 603303).

Draba glabella Pursh (Smooth Draba, drave glabre) [circumboreal-polar] – NUNAVUT: Somerset Island, western cliff wall of Gull Canyon, below gull nesting area, wet rocks directly under water seeps and waterfall, dense lush vegetation, with *Saxifraga cespitosa, Bistorta vivipara, Saxifraga cernua*, bryophytes, 74°3'48.4"N, 93°40'57.2"W, 40 m, 7 July 2013, *P. Sokoloff 134* (CAN 603304).

Draba lactea Adams (Milky Draba, drave laiteuse) [circumpolar] – NUNAVUT: Somerset Island, Cunningham Inlet, 1.6 km from inlet, uplands, polar desert, sedge meadow, 74°06'N, 93°55'W, 20 m, 22 July 1976, *L.C. Bliss s.n.* (ALTA 56712);

Draba nivalis Liljebkad (Snow Draba, drave des neiges) [circumpolar-alpine] – NUNAVUT: Somerset Island, south end of Sunday Lake, north of Cunningham River, 7 km south of Arctic Watch Lodge, lemming mound in middle of mud flats, 74°0'23.3"N, 93°42'43.5"W, 41 m, 11 July 2013, *P. Sokoloff 228* (CAN 603305).

Draba simmonsii Elven & Al-Shebaz (Simmons' Draba, drave de Simmons) [North American] – NUNAVUT: Somerset Island, gravelly scree ledge above Cunningham River, directly adjacent to Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 8 July 2013, *P. Sokoloff 152* (CAN 603306).

Draba subcapitata Simmons (Ellesmere Island Draba, drave subcapitée) [circumpolar] – NUNAVUT: Somerset Island, scarce on dry gravel slope, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3786* (DAO 525915).

Eutrema edwardsii R. Brown (Edwards' Mock Wallflower, eutréma d'Edwards) [circumpolar-alpine] – NUNAVUT: Somerset Island, Cunningham Inlet, 1.6 km from inlet, Stand 15, uplands, polar desert, sedge meadow, 74°06'N, 93°55'W, 20 m, 22 July 1976, *L.C. Bliss s.n.* (ALTA 56711).

Parrya arctica R. Brown (Arctic False Wallflower, parrya arctique) [North American] – NUNAVUT: Somerset Island, Cunningham Inlet, 0.16 km from inlet, uplands, polar desert, coastal beach ridge, 74°06'N, 93°55'W, 20 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56729); Cunningham Inlet, on a mild slope, with *Dryas integrifolia*, 74°6'00"N, 93°51'00"W, 63 m, 13 July 2004, *A. Archambault & L. Consaul aa48* (CAN 603404), *aa49* (CAN 603403), *aa52* (CAN 603402), *aa53* (CAN 603401), *aa55* (CAN 603399), *aa56* (CAN 603397), *aa57* (CAN 603398), *aa59* (CAN 603405); scattered on dry calcareous gravel slope, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3783* (DAO 567232); Cunningham Inlet, 74°N, 94°W, 7 August 1949, *B. Shindman s.n.* (DAO 567235); west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, tundra in dry mud, with *Dryas integrifolia*, 74°3'41.1"N, 93°41'18.8"W, 50 m, 7 July 2013, *P. Sokoloff 126* (CAN 603307); wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, dry mud and clay mound in wet turfy tundra, with *Festuca* sp., 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 180* (CAN 603308); wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, wet mossy tundra, with *Eriophorum angustifolium*, 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 185* (CAN 603309); south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 224* (CAN 603310); shoreline on north coast of Somerset Island, 7 km west of entrance to Cunningham Inlet, rocky, snow-pack mountain, with *Parry arctica, Saxifraga oppositifolia, Salix arctica*, 74°7'56.9"N, 94°11'21.8"W, 23 m, 11 July 2013, *P. Sokoloff, Z. Halem 242* (CAN 603311).

Caryophyllaceae

Cerastium arcticum Lange (Arctic Chickweed, céraiste arctique, Nunarait qakuqtat) [North American–amphi-Atlantic–European] – NUNAVUT: Somerset Island, Cunningham Inlet, 8 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 200 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56720); west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, dry rocky scree, with *Xanthoria elegans, Festuca* sp., *Saxifraga oppositifolia*, 74°3'42.4"N, 93°40'47.8"W, 50 m, 7 July 2013, *P. Sokoloff 131* (CAN 603312); confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 148* (CAN 603313); gravelly scree ledge above Cunningham River, directly adjacent to Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 8 July 2013, *P. Sokoloff 155* (CAN 603314).

Cerastium beeringianum Chamussi & Schlechtendal (Bering Sea Chickweed, céraiste du détroit de Béring) [Asian–amphi-Beringian–North American] – NUNAVUT: Somerset Island, occasional on slightly moist calcareous gravel slopes, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3784* (DAO 562713).

Cerastium regelii Ostenfeld (Regel's Chickweed, céraiste de Regel) [circumpolar] – NUNAVUT: Somerset Island, dry stone ridge immediately west of Arctic Watch Lodge, east-facing wet muddy snow bed set in shale rocks, with *Luzula confusa, Sabulina rubella*, 74°4'21.3"N, 93°50'30.7"W, 122 m, July 6, 2013, *P. Sokoloff 119* (CAN 603315).

Sabulina rossii (R. Brown ex Richardson) Dillenberger & Kadereit (Ross' Stitchwort, sabline de Ross) [amphi-Beringian–North American–amphi-Atlantic] – NUNAVUT: Somerset Island, Cunningham Inlet, 8 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 200 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 72149); north-facing ridge west of Arctic Watch Lodge, *Eriophorum-Arctagrostis* meadow, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 169* (CAN 603316); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 201* (CAN 603317).

Sabulina rubella (Wahlenberg) Dillenberger & Kadereit (Reddish Stitchwort, sabline rougeâtre, Kakillarnait) [circumpolar-alpine] – NUNAVUT: Somerset Island, scarce on calcareous gravel slope, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3787* (DAO 527824); Cunningham Inlet, 8 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 200 m, 20 July 1976, *L.C. Bliss s.n.* (ALTA 56728); dry stone ridge immediately west of Arctic Watch Lodge, east-facing wet muddy snow bed set in shale rocks, with *Luzula confusa*, 74°4'21.3"N, 93°50'30.7"W, 122 m, July 6, 2013, *P. Sokoloff 118* (CAN 603318); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 202* (CAN 603319); south end of Sunday Lake, 6 km south of Arctic Watch Lodge, mossy knoll in wet tundra, 74°1'7.8"N, 93°45'41.5"W, 66 m, 11 July 2013, *P. Sokoloff 213* (CAN 603320); lemming mound at top of hill at south end of Sunday Lake, 7 km south of Arctic Watch Lodge, with *Potentilla* sp., *Alopecurus magellanicus*, 74°0'38.8"N, 93°44'30.4"W, 49 m, 11 July 2013, *P. Sokoloff 219* (CAN 603321).

Silene uralensis (Ruprecht) Bocquet ssp. *uralensis* (Nodding Catchfly, silène de l'Oural, Pulluliujuit) [European–Asian–amphi-Beringian–North American] – NUNAVUT: Somerset Island, scattered on wet gravelly slope, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3781* (DAO 537745); gravelly scree ledge above Cunningham River, directly adjacent of Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 8 July 2013, *P. Sokoloff 153* (CAN 603322).

Stellaria longipes Goldie (Long-stalked Starwort, stellaire à longs pédicelles, Miqqaviat) [circumboreal-polar] – Nunavut: Somerset Island, confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, with *Cerastium arcticum*, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 145* (CAN 603323); wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, dry mud and clay mound in wet turfy tundra, with *Festuca* sp., 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 182* (CAN 603324, NFM); gravelly scree ledge above Cunningham River, 9.6 km southeast of Arctic Watch Lodge, muddy bank, 73°59'27.3"N, 93°40'57.5"W, 69 m, 11 July 2013, *P. Sokoloff 235* (CAN 603325, US); gravelly scree ledge above Cunningham River, 9.6 km southeast of Arctic Watch Lodge, muddy bank, 73°59'27.3"N, 93°40'57.5"W, 69 m, 11 July 2013, *P. Sokoloff 236* (CAN 603326).

Cyperaceae

Carex aquatilis var. *minor* Boott (Arctic Water Sedge, carex mineur, Kilirnait) [circumboreal-polar] – Nunavut: Somerset Island, south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 244* (CAN 603328).

Carex capillaris ssp. *fuscidula* (V.I. Kreczetovicz ex T.V. Egorova) Á. Löve & D. Löve (Dusky-spike Sedge, carex à epis sombres) [circumpolar-alpine] – Nunavut: Somerset Island, Cunningham Inlet, 1.6 km from inlet, Stand 15, uplands, polar desert, sedge meadow, 74°06'N, 93°55'W, 20 m, 22 July 1976, *L.C. Bliss s.n.* (ALTA 56726); north-facing slope west of Arctic Watch Lodge, wet rocky seep in *Dryas–Eriophorum* tundra, with *Dryas integrifolia, Salix arctica, Draba corymbosa, Cerastium arcticum*, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 168* (CAN 603329); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet *Dryas* tundra with snowbed community, with *Saxifraga oppositifolia, Salix arctica*, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 207* (CAN 603330).

Carex membranacea Hooker (Fragile Sedge, carex membraneux, Kilirnait ajjikasangit iviit) [amphi-Beringian–North American] – Nunavut: Somerset Island, scattered in small sedge meadow below limestone hill, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3777* (DAO 363708).

Eriophorum triste (Th. Fries) Hadač & Á. Löve (Tall Cottongrass, linaigrette triste) [amphi-Beringian–North American–amphi-Atlantic] – Nunavut: Somerset Island, Cunningham Inlet, 1.6 km from inlet, wet sedge tundra, sedge meadow, 74°06'N, 93°55'W, 20 m, 22 July 1976, *L.C. Bliss s.n.* (ALTA 56715); North-facing ridge west of Arctic Watch Lodge, *Eriophorum–Arctagrostis* meadow, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 170* (CAN 603335, US); south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 222* (CAN 603336); south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 223* (CAN 603337).

Juncaceae

Juncus biglumis L. (Two-flowered Rush, jonc à deux glumes, Iviit) [circumpolar-alpine] – Nunavut: Somerset Island, occasional on wet calcareous slopes, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3778* (DAO 781829); Cunningham Inlet, 1.6 km from inlet, wet sedge tundra, coastal lowland beach ridges, 74°06'N, 93°55'W, 20 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56721); north-facing slope west of Arctic Watch Lodge, wet rocky seep in *Dryas–Eriophorum* tundra, with *Dryas integrifolia, Salix arctica, Draba corymbosa, Cerastium arcticum*, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 166* (CAN 603341, US); wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, wet mossy tundra, with *Eriophorum angustifolium*, 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 183* (CAN 603342).

Luzula nivalis (Laestadius) Sprengel (Arctic Woodrush, luzule arctique) [circumpolar-alpine] – Nunavut: Somerset Island, scattered on moist calcareous slopes, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3782* (DAO 780607); dry stone ridge immediately west of Arctic Watch Lodge, east-facing wet muddy snow bed set in shale rocks, with *Sabulina rubella*, 74°4'21.3"N, 93°50'30.7"W, 122 m, July 6, 2013, *P. Sokoloff 117* (CAN 603343); north-facing slope west of Arctic Watch Lodge, wet rocky seep in *Dryas–Eriophorum* tundra, with *Dryas integrifolia, Salix arctica, Draba corymbosa, Cerastium arcticum*, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 167* (CAN 603344); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 199* (CAN 603345, US).

Orobanchaceae

Pedicularis lanata Willdenow ex Chamisso & Schlechtendal (Woolly Lousewort, pédiculaire laineuse, Ugjungnaq) [amphi-Beringian–North American] – Nunavut: Somerset Island, south end of Sunday Lake, 6 km south of Arctic Watch Lodge, wet *Salix–Dryas* meadow, 74°0'51.7"N, 93°44'57.6"W, 64 m, 11 July 2013, *P. Sokoloff 216* (CAN 603347); south end of Sunday Lake, 7 km south of Arctic Watch Lodge, wet *Eriophorum* meadow, 74°0'24.9"N, 93°43'40.9"W, 26 m, 11 July 2013, *P. Sokoloff 225* (CAN 603348).

Papaveraceae

Papaver cornwallisense D. Löve (Cornwallis Island Poppy, pavot de Cornwallis) [North American–amphi-

Atlantic] – NUNAVUT: Somerset Island, Cunningham Inlet, 0.16 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 20 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56725); Cunningham Inlet, 0.16 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 20 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56710); dry stone ridge immediately west of Arctic Watch Lodge, in gravel scree, dry slaty gravel, with *Saxifraga oppositifolia, Salix arctica, Papaver* sp., 74°4'20.2"N, 93°49'22.6"W, 20 m, July 6, 2013, *P. Sokoloff 115* (CAN 603349); western cliff wall of Gull Canyon, below Gull nesting area, wet rocks directly under water seeps and waterfall, dense lush vegetation, with *Saxifraga cespitosa, Bistorta vivipara, Saxifraga cernua*, bryophytes, 74°3'48.4"N, 93°40'57.2"W, 40 m, 7 July 2013, *P. Sokoloff 136* (CAN 603350); gravelly scree ledge above Cunningham River, directly adjacent to Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 8 July 2013, *P. Sokoloff 150* (CAN 603351); south end of Sunday Lake, north of Cunningham River, 7 km south of Arctic Watch Lodge, mud flats, 74°0'23.3"N, 93°42'43.5"W, 41 m, 11 July 2013, *P. Sokoloff 231* (CAN 603352).

Poaceae

Alopecurus magellanicus Lamarck (Alpine Foxtail, vulpin boréal, Ivi) [circumpolar-alpine and South American] – NUNAVUT: Somerset Island, site no. Z-25, level lacustrine well- to imperfectly drained silt plain, grass-saxifrage foxhole mound, 74°2'N, 93°30'W, 53 m, 260 m, July 1, 1975, *S.C. Zoltai 751152* (DAO 137589); mound at top of hill at south end of Sunday Lake, 7 km south of Arctic Watch Lodge, lush lemming mound, with *Potentilla* sp., *Sabulina rubella*, 74°0'38.8"N, 93°44'30.4"W, 49 m, 11 July 2013, *P. Sokoloff 218* (CAN 603353); south end of Sunday Lake, north of Cunningham River, 7 km south of Arctic Watch Lodge, lemming mound in middle of mud flats, 74°0'23.3"N, 93°42'43.5"W, 41 m, 11 July 2013, *P. Sokoloff 226* (CAN 603354); confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, with bryophytes, *Cerastium arcticum*, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 143b* (CAN 603355).

Arctagrostis latifolia (R. Brown) Grisebach ssp. *latifolia* (Polargrass, arctagrostide à larges feuilles) [circumpolar-alpine] – NUNAVUT: Somerset Island, Cunningham Inlet, 1.6 km from inlet, wet sedge tundra on coastal lowlands, 74°06'N, 93°55'W, 20 m, 23 July 1976, *L.C. Bliss s.n.*, (ALTA 56714); alluvial plain of Cunningham River on Cunningham Inlet, 3 km east of Arctic Watch Lodge, wet sedge meadow emerging from melting snowbank, with *Deschampsia* sp., *Poa* sp., 74°3'40.1"N, 93°42'17.6"W, 40 m, 7 July 2013, *P. Sokoloff 121* (CAN 603356); north-facing ridge west of Arctic Watch Lodge, *Eriophorum–Arctagrostis* meadow, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 172* (CAN 603357).

Arctophila fulva (Trinius) Andersson (Pendant Grass, arctophile fauve) [circumpolar] – NUNAVUT: Somerset Island, site no. Z-44, level fen with poorly drained organic soil, with *Drepanocladus* sp., 74°1'N, 93°27'W, 53 m, 14 July 1975, *S. C. Zoltai 751114* (DAO 137672).

Deschampsia brevifolia R. Brown (Short-leaved Hairgrass, deschampsie à feuilles courtes) [Asian–amphi-Beringian–North American] – NUNAVUT: Somerset Island, alluvial plain of Cunningham River on Cunningham Inlet, 3 km east of Arctic Watch Lodge, wet sedge meadow emerging from melting snowbank, with *Poa* sp., *Arctagrostis* sp., 74°3'40.1"N, 93°42'17.6"W, 40 m, 7 July 2013, *P. Sokoloff 122* (CAN 603358); alluvial plain of Cunningham River on Cunningham Inlet, 3 km east of Arctic Watch Lodge, wet sedge meadow emerging from melting snowbank, with *Poa* sp., *Arctagrostis* sp., 74°3'40.1"N, 93°42'17.6"W, 40 m, 7 July 2013, *P. Sokoloff 123* (CAN 603359); north-facing ridge west of Arctic Watch Lodge, *Eriophorum–Arctagrostis* meadow, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 173* (CAN 603360, US); south end of Sunday Lake, 6 km south of Arctic Watch Lodge, mossy knoll in wet tundra, 74°1'7.8"N, 93°45'41.5"W, 66 m, 11 July 2013, *P. Sokoloff 215* (CAN 603361).

Festuca baffinensis Polunin (Baffin Island Fescue, fétuque de Baffin) [Asian–amphi-Beringian–North American–amphi-Atlantic] – NUNAVUT: Somerset Island, site no. Z-25, level lacustrine well- to imperfectly drained silt plain, grass-saxifrage foxhole mound, 74°2'N, 93°30'W, 53 m, 1 July 1975, *S. C. Zoltai 751153* (DAO 137687).

Festuca brachyphylla Schultes & Schultes f. (Short-leaved Fescue, fétuque à feuilles courtes, Ivilsugait) [circumpolar-alpine] – NUNAVUT: Somerset Island, confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, with bryophytes, *Cerastium arcticum*, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 146* (CAN 603362).

Festuca edlundiae S.G. Aiken, Consaul & Lefkovitch (Edlund's Fescue, fétuque d'Edlund) [amphi-Beringian–North American–amphi-Atlantic] – NUNAVUT: Somerset Island, west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, dry rocky scree, with *Xanthoria elegans, Saxifraga oppositifolia*, 74°3'42.4"N, 93°40'47.8"W, 50 m, 7 July 2013, *P. Sokoloff 128* (CAN 603363).

Poa abbreviata R. Brown ssp. *abbreviata* (Dwarf Bluegrass, pâturin court) [nearly circumpolar] – NUNAVUT: Somerset Island, scarce on moist calcareous slope, 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3780* (DAO 57589); Cunningham Inlet, 8 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 225 m, 20 July 1976, *L.C. Bliss s.n.*, (ALTA 56727); Cunningham Inlet, 8 km from inlet, uplands, polar desert, coastal lowlands, 74°06'N, 93°55'W, 30 m, 23 July 1976, *L.C. Bliss s.n.*, (ALTA 56716).

Poa arctica R. Brown (Arctic Bluegrass, pâturin arctique) [circumpolar-alpine] – NUNAVUT: Somerset Island, Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 198* (CAN 603364).

Puccinellia bruggemannii T.J. Sørensen (Prince Patrick Alkaligrass, puccinellie de Bruggemann) [North American] – NUNAVUT: Somerset Island, Cunningham Inlet, 1.6 km from inlet, uplands, polar desert, sedge meadow, 74°06'N, 93°55'W, 20 m, 22 July 1976, *L.C. Bliss s.n.*, (ALTA 56719); on wet gravel and clay soil, 74°6'00"N, 93°51'00"W, 63 m, July 13, 2004, *L. Consaul & A. Archambault 3083* (CAN 603396).

Puccinellia vahliana (Liebmann) Scribner & Merrill (Vahl's Alkaligrass, puccinellie de Vahl) [North American–amphi-Atlantic] – NUNAVUT: Somerset Island, on wet gravel and clay soil, 74°6'00"N, 93°51'00"W, 63 m, July 13, 2004, *L. Consaul & A. Archambault 3082* (CAN 603395); north-facing slope west of Arctic Watch Lodge, wet rocky seep in *Dryas–Eriophorum* tundra, with *Dryas integrifolia, Salix arctica, Draba corymbosa, Cerastium arcticum*, 74°4'17.5"N, 93°49'17.2"W, 16 m, 9 July 2013, *P. Sokoloff 189* (CAN 603366).

Trisetum spicatum (L.) K. Richter (Narrow False Oats, trisète à epi, Iviit iviksugait) [circumpolar-alpine] – NUNAVUT: Somerset Island, confluence of Cunningham River and stream immediately south of Arctic Watch Lodge at Cunningham River crossing, rocky talus on south-facing slope, with bryophytes, *Cerastium arcticum*, 74°4'2.9"N, 93°48'31.7"W, 58 m, 8 July 2013, *P. Sokoloff 144* (CAN 603370).

Polygonaceae

Bistorta vivipara (L.) Delarbre (Alpine Bistort, renouée vivipare, Sapangaralannguat) [circumboreal-polar] – NUNAVUT: Somerset Island, Cunningham Inlet, 1.6 km from inlet, uplands, polar desert, sedge meadow, 74°06'N, 93°55'W, 20 m, 22 July 1976, *L.C. Bliss s.n.* (ALTA 56713); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet *Dryas* tundra with snow-bed community, with *Saxifraga oppositifolia, Salix arctica*, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 209* (CAN 603371).

Oxyria digyna (L.) Hill (Mountain Sorrel, oxyrie de montagne, Qunguliit) [circumpolar-alpine] – NUNAVUT: Somerset Island, south end of Sunday Lake, 6 km south of Arctic Watch Lodge, mossy knoll in wet tundra, 74°1'7.8"N, 93°45'41.5"W, 66 m, 11 July 2013, *P. Sokoloff 212* (CAN 603372); mud flats on alluvial slope to Cunningham River, south of Sunday lake, 9 km south of Arctic Watch Lodge, mud flats alongside river, 73°59'16.5"N, 93°41'38.7"W, 40 m, 11 July 2013, *P. Sokoloff 237* (CAN 603373).

Rosaceae

Dryas integrifolia Vahl (Entire-leaved Mountain Avens, dryade à feuilles entières, Malikkaat) [amphi-Beringian North American] NUNAVUT: Somerset Island, Cunningham Inlet, 0.16 km from inlet, uplands, polar desert, coastal lowland beach ridges, 74°06'N, 93°55'W, 30 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56730); north-facing ridge west of Arctic Watch Lodge, *Eriophorum–Arctagrostis* meadow, 74°4'27.7"N, 93°50'39.4"W, 118 m, 9 July 2013, *P. Sokoloff 174* (CAN 603374); 2 km south of point at Cape Anne, muddy wet ground in marshy field alongside river, with *Saxifraga oppositifolia, Salix arctica, Dryas integrifolia*, bryophytes, 74°6'23.3"N, 94°23'44.25"W, 26 m, 10 July 2013, *P. Sokoloff, Z. Halem 240* (CAN 603375).

Potentilla pulchella R. Brown (Pretty Cinquefoil, potentille jolie) [circumpolar] – NUNAVUT: Somerset Island, lemming mound at top of hill at south end of Sunday Lake, 7 km south of Arctic Watch Lodge, lush lemming mound, with *Arctagrostis* sp., *Sabulina rubella*, 74°0'38.8"N, 93°44'30.4"W, 49 m, 11 July 2013, *P. Sokoloff 217* (CAN 603376); south end of Sunday Lake, north of Cunningham River, 7 km south of Arctic Watch Lodge, lemming mound in middle of mud flats, 74°0'23.3"N, 93°42'43.5"W, 41 m, 11 July 2013, *P. Sokoloff 227* (CAN 603377).

Salicaceae

Salix arctica Pallas (Arctic Willow, saule arctique, Suputiit, Suputiksaliit, Uqaujait) [circumpolar-alpine] – NUNAVUT: Somerset Island, Cunningham Inlet, 1.6 km from inlet, uplands, polar desert, coastal lowland beach ridges, 74°06'N, 93°55'W, 30 m, 23 July 1976, *L. C. Bliss s.n.* (ALTA 56718); dry stone ridge immediately west of Arctic Watch Lodge, in gravel scree, dry slaty gravel, with *Saxifraga oppositifolia, Salix arctica, Papaver* sp., 74°4'20.2"N, 93°49'22.6"W, 20 m, July 6, 2013, *P. Sokoloff 113* (CAN 603379); dry stone ridge immediately west of Arctic Watch Lodge, in gravel scree, dry slaty gravel, with *Saxifraga oppositifolia, Salix arctica, Papaver* sp., 74°4'20.2"N, 93°49'22.6"W, 20 m, July 6, 2013, *P. Sokoloff 114* (CAN 603380); gravelly scree ledge above Cunningham River, directly adjacent to Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 9 July 2013, *P. Sokoloff 164* (CAN 603381); wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, wet sedge meadow emerging from melting snowbank, with *Stellaria longipes, Cerastium arcticum*, bryophytes, 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 178* (CAN 603382); garden spot below sewage lagoon at Arctic Watch Lodge, lush green patch in rocky scree, with *Salix arctica, Saxifraga oppositifolia, Papaver* sp., *Parrya arctica*, bryophytes, 74°4'13.1"N, 93°48'55.8"W, 16 m, 9 July 2013, *P. Sokoloff 188* (CAN 603383); 2 km south of point at Cape Anne, muddy wet ground in marshy field alongside river, with *Saxifraga oppositifolia, Salix arctica,* *Dryas integrifolia*, bryophytes, 74°6'23.3"N, 94°23'44.25"W, 26 m, 10 July 2013, *P. Sokoloff, Z. Halem 238* (CAN 603384); garden spot below sewage lagoon at Arctic Watch Lodge, lush green patch in rocky scree, with *Salix arctica, Saxifraga oppositifolia, Papaver* sp., *Parrya arctica*, bryophytes, 74°4'13.1"N, 93°48'55.8"W, 16 m, July 12, 2013, *P. Sokoloff, A. Manik 243* (CAN 603385).

Saxifragaceae

Micranthes nivalis (L.) Small (Snow Saxifrage, saxifrage des neiges) [circumpolar-alpine] – NUNAVUT: Somerset Island, Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 203* (CAN 603386).

Saxifraga cernua L. (Nodding Saxifrage, saxifrage penchée, Nunaraq qupanuap niqinga) [circumpolar-alpine] – NUNAVUT: Somerset Island, western cliff wall of Gull Canyon, below Gull nesting area, wet rocks directly under water seeps and waterfall, dense lush vegetation, with *Saxifraga cespitosa, Bistorta vivipara*, bryophytes, 74°3'48.4"N, 93°40'57.2"W, 40 m, 7 July 2013, *P. Sokoloff 133* (CAN 603387); gravelly scree ledge above Cunningham River, directly adjacent to Arctic Watch Lodge (north side), rocky talus irrigated by water pipe, with *Draba corymbosa*, 74°4'10.8"N, 93°48'37.4"W, 58 m, 8 July 2013, *P. Sokoloff 154* (CAN 603388).

Saxifraga cespitosa L. (Tufted Saxifrage, saxifrage cespiteuse) [circumpolar-alpine] – NUNAVUT: Somerset Island, Cunningham Inlet, 0.16 km from inlet, uplands, polar desert, coastal lowland beach ridges, 74°06'N, 93°55'W, 30 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56722); dry stone ridge immediately west of Arctic Watch Lodge, in gravel scree, wet seep under boulder in shale and muddy rock, with *Cerastium arcticum, Papaver* sp., *Saxifraga oppositifolia*, 74°4'21.3"N, 93°50'30.7"W, 122 m, July 6, 2013, *P. Sokoloff 116* (CAN 603389, NFM); Flat Rock Falls, east coast of Cunningham Inlet, 4 km northeast of Arctic Watch Lodge, wet snow-patch community at foot of packed snowbank, near foot of falls, 74°5'56.1"N, 93°44'18.5"W, 55 m, 10 July 2013, *P. Sokoloff 200* (CAN 603390); garden spot below sewage lagoon at Arctic Watch Lodge, lush green patch in rocky scree, with *Salix arctica, Saxifraga oppositifolia, Papaver* sp., *Parrya arctica*, bryophytes, 74°4'13.1"N, 93°48'55.8"W, 16 m, July 12, 2013, *P. Sokoloff 246* (CAN 603391).

Saxifraga oppositifolia L. (Purple Mountain Saxifrage, saxifrage à feuilles opposées, Aupilattunnguat) [circumpolar-alpine] – NUNAVUT: Somerset Island, common especially on moist calcareous gravel slopes., 74°6'N, 93°51'W, 11 August 1958, *D.B.O. Savile 3785* (DAO 886692); Cunningham Inlet, 0.16 km from inlet, uplands, polar desert, 74°06'N, 93°55'W, 20 m, 23 July 1976, *L.C. Bliss s.n.* (ALTA 56732); Cunningham Inlet, 8 km from inlet, uplands, polar desert, Somerset plateau, 74°06'N, 93°55'W, 200 m, 20 July 1976, *L.C. Bliss s.n.* (ALTA 56731); west ridge overlooking Gull Canyon, 4 km east of Arctic Watch Lodge, dry rocky scree, with *Xanthoria elegans, Festuca* sp., 74°3'42.4"N, 93°40'47.8"W, 50 m, 7 July 2013, *P. Sokoloff 127* (CAN 603392); wet snowmelt valley at base of large unnamed mountain northwest of Arctic Watch Lodge, dry mud and clay mound in wet turfy tundra, with *Festuca* sp., 74°4'31.3"N, 93°51'1.7"W, 122 m, 9 July 2013, *P. Sokoloff 181* (CAN 603393, NFM).

Saxifraga flagellaris ssp. *platysepala* (Trautvetter) A.E. Porsild (Spider Saxifrage, saxifrage à sépales larges, Kakillarnaliit) [circumpolar] – NUNAVUT: Somerset Island, mossy wet area outside whale biologist's cabin, 1.5 km north of Arctic Watch Lodge, wet mossy rocks, with *Saxifraga cernua, Luzula confusa, Draba* sp., *Salix arctica*, 74°4'58.8"N, 93°50'2"W, 94 m, 8 July 2013, *P. Sokoloff 156* (CAN 603394).

Discussion

Although five botanical collecting trips have taken place on Cunningham Inlet, the four trips previous to this study were focused primarily on selective collecting or ecological assessment. Combining these data with the 93 vascular plant specimens collected in 2013 provides a relatively complete inventory of the vascular plants of Cunningham Inlet.

Although the 48 vascular plant species documented is a relatively low number in terms of the species diversity over the entire island (40% of those reported in Aiken *et al.* 2007, 48% of those in Savile 1959, and 64% of those in Woo and Zoltai 1959), it is important to consider that Cunningham Inlet is well within the "cryptogam–herb barren" vegetation unit described in the Circumpolar Arctic Vegetation Map, which covers only roughly half of the island (Walker *et al.* 2005). The dominant growth forms described for this vegetation unit include "Cushion forbs: *Papaver dahlianum* ssp. *polare*; *Draba*; *Potentilla hyparctica*; *Saxifraga oppositifolia*" and "Graminoid: *Alopecurus alpinus; Deschampsia borealis/brevifolia*; *Poa abbreviata*; *Puccinellia angustata*; *Phippsia*; *Luzula nivalis*; *Luzula confusa*" (CAVM Team 2003*), nearly all of which are documented in this paper. Cunningham Inlet is also classified by the Circumpolar Arctic Vegetation Map Team as belonging to Arctic Bioclimate Subzone B, where prostrate dwarf shrubs (such as Arctic Willow) are the dominant growth form, and the number of species is estimated to run from 50 to 100 depending on the site (CAVM Team 2003*). Considering the ecology of Cunningham Inlet's polar desert and the five collecting trips to this site, it seems highly likely that we have documented all the vascular plants at this inlet and that the remaining species known for Somerset Island occur within the other ecosystems found on the island.

FIGURE 3: Edlund's Fescue (*Festuca edlundiae* S.G. Aiken, Consaul & Lefkovitch) in habitat at the top of cliffs overlooking Gull Canyon, Somerset Island, Nunavut (*Sokoloff 128*). Photo by P. Sokoloff.

The summer of 2013 was unusually cold and late in the Canadian high Arctic (NASA 2013*), which delayed the flowering time of many species we encountered. Many species found on the open tundra had just begun their yearly growth, and the Purple Mountain Saxifrage, a benchmark spring ephemeral species in the Arctic, was still in full bloom when I left Cunningham Inlet. Although this resulted in taxonomically useful plant specimens rarely collected in flower (i.e., *Saxifraga oppositifolia* and *Salix arctica*), care should be taken to look for late-flowering specimens and specimens with fruits on subsequent visits to Cunningham Inlet. Thus, although comparisons between past and current vascular plant communities at this site are impossible given the paucity of earlier collections, in the future Cunningham Inlet could be used to monitor floristic change in the high Arctic using this inventory as a baseline, while keeping an eye out for any additions to the flora that would have been missed because of their later flowering time.

Two vascular plant species reported here, *Festuca edlundiae* (Figure 3) and *Draba glabella*, have not been reported before for Somerset Island (Savile 1959; Aiken *et al.* 2007). *Festuca edlundiae* is a widespread Canadian high Arctic endemic, found throughout the northern part of the archipelago, including Cornwallis and Prince of Wales Islands, adjacent to Somerset Island (Aiken *et al.* 2007). This species has only recently been recognized as a distinct taxon within the Canadian high Arctic *Festuca brachyphylla* complex (Aiken *et al.* 1995). Dwarf plants with a heavily marcescent habit, *Festuca edlundiae*, were first differentiated from the phenotypically variable *Festuca hyperborea* Holmen ex Frederiksen (High Arctic Fescue) based on isozymes (Aiken *et al.* 1995). Hybridization and introgression between *Festuca edlundiae* and the other high Arctic *Festuca* species have been documented (Saarela *et al.* 2013), but taxonomic boundaries between the various species are well understood and various keys exist separating the species using consistent morphologic characters (Fjellheim *et al.* 2001; Guldahl *et al.* 2001). Using these keys, it may yet be found that *Festuca edlundiae* has been collected on Somerset Island before its recognition as a distinct taxon; nonetheless *Sokoloff 128* is the first known report of this grass species on the island.

Draba glabella (*Sokoloff 134*) is a first collection for both Somerset Island and the central Canadian Arctic archipelago. This species is common and widespread within the archipelago, but although its distribution extends from Banks to Baffin Island (east to west) and from the mainland to Ellesmere Island (south to north), it is absent from the central Arctic islands, including Bathurst, Prince William, and Cornwallis (Aiken *et al.* 2007), and has been reported only once on the west coast of Devon Island by Polunin (1940;

FIGURE 4: Habitat of Smooth Draba (*Draba glabella* Pursh) at Gull Canyon, Somerset Island, Nunavut. *Draba glabella* (*Sokoloff 134*) was collected at the base of the cliffs on the right side of the canyon. Photo by P. Sokoloff.

a second report in this volume is apparently a typo, a repetition of a collection made on Sugluk Island just off the coast of Quebec). These central islands are primarily polar desert (including the study site at Cunningham Inlet) and consist of shattered limestone with minimal tundra cover (Savile 1959; Bliss *et al.* 1984).

Accordingly, we found *Draba glabella* growing at only a single site: in wet moss and rich soil at a gull colony (Figure 4). Burt (2000) and Polunin (1940) indicate that such damp, nutrient- and soil-rich cliffs are ideal habitat for *Draba glabella*. Our discovery of this species at a bird colony in the middle of a gap in its range (Aiken *et al.* 2007) either points to bird-borne dispersal of the plant or indicates that this colony may serve as a refuge for this species in otherwise inhospitable and nutrient-poor habitat (Odasz 1994). In either case, other bird colonies within the central Canadian polar desert could harbour this widespread species as well.

The four identified species of marine algae, *Fucus distichus*, *Alaria esculenta*, *Agarum cribrosum*, and *Sacharrina latissima*, are all previously known to occur in the Barrow Straight, and both *Alaria esculenta* and *Fucus distichus* have been previously collected in Cunnigham Inlet (Lee 1980). *Nostoc commune*, known to be common in the Canadian high Arctic (Polunin 1947; Lennihan *et al.* 1994; Sheath *et al.* 1996), is poorly represented in Canadian algal collections (CANA, data available through Canadensys). Thus, *Sokoloff 175* and *176* are likely the first known specimens of *Nostoc commune* from Somerset Island.

Although our 20 lichen and 13 bryophyte specimens greatly expand on known cryptogamic species from Somerset Island (Savile 1959), they were collected opportunistically and there are almost certainly gaps in the collection that a trained lichenologist or bryologist could fill.

Acknowledgements

I am immensely grateful to the following people who provided identification for many specialized taxonomic groups: Dr. Jeffery Saarela (Poacaeae, Cyperaceae, Juncaceae), Paul Hamilton (algae), Colin Freebury (lichens), Jennifer Doubt (bryophytes), Dr. Lynn Gillespie (*Papaver*, *Potentilla*), Étienne Léveillé-Bourret (*Potentilla*), and Gerry Mulligan (*Draba*). I thank Micheline Beaulieu-Bouchard, Jennifer Doubt, Amaina Boloron, Laura Smyk, and the Canadian Museum of Nature's botany volunteers for processing this collection. I thank Dr. Jeff Saarela for thoughtful comments on this manuscript. I also thank Gisele Mitrow and Amanda Ward for providing helpful access to the Agriculture and Agri-Food Canada collection of vascular plants. Comments by Dr. Jacques Cayouette and

Dr. Paul Catling greatly enhanced earlier drafts of this work. This fieldwork was carried out as part of Arctic Watch Lodge's 2013 Steve Amarualik Youth Leadership Expedition and would not have been possible without the generous support of Arctic Watch Lodge and the Canadian Museum of Nature. In particular, I thank Richard Weber, Josée Auclair, Tessum Weber, Nansen Weber, and Ewan Affleck for organizing an exceptional expedition for the youth participants, for hosting me at Arctic Watch Lodge, and for going out of their way to contribute to the success of the collecting portion of the trip. Zach Halem and Alicia Malik both contributed as able collectors, and I commend all the expedition's youth — Alicia, Anika, Belinda, Louis, Savannah, Simeonie, Ryan, Sky, and Zach — for their enthusiasm, curiosity, and assistance. This research was conducted under Nunavut Department of Environment Wildlife research permit WL 2013-026.

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Received 25 March 2014
Accepted 17 June 2014

Osmia species (Megachilidae) Pollinate *Cypripedium parviflorum* (Orchidaceae) and *Packera paupercula* (Asteraceae): A Localized Case of Batesian Mimicry?

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Catling, Paul M. 2015. *Osmia* species (Megachilidae) pollinate *Cypripedium parviflorum* (Orchidaceae) and *Packera paupercula* (Asteraceae): a localized case of Batesian mimicry? Canadian Field-Naturalist 129(1): 38–44.

The pollinator-non-rewarding Large Yellow Lady's-slipper (*Cypripedium parviflorum* var. *pubescens* [Willdenow] Knight) and the rewarding Balsam Ragwort (*Packera paupercula* [Michaux] Á. Löve & D. Löve) exist together in some eastern Ontario alvars where they share a group of medium-sized, dark blue metallic pollinators in the bee genus *Osmia* (Mason Bees, Megachilidae). I provide evidence of floral mimicry of the ragwort by the orchid based on several observations: (1) *Osmia* visiting *P. paupercula* also visit *C. parviflorum* var. *pubescens*; (2) *Osmia* are more frequent visitors to *P. paupercula* than to other co-blooming plants; (3) *Osmia* are the primary pollinators of *C. parviflorum* var. *pubescens*; (4) the behaviour of *Osmia* on the flower of *C. parviflorum* var. *pubescens* involving landing on the staminode suggests mimicry; and (5) the largest populations of *C. parviflorum* var. *pubescens* in Ontario are in alvar landscapes where *P. paupercula* is abundant. Pollination in Large Yellow Lady's-slipper may vary geographically from non-model to species-specific Batesian mimicry, which is rare in orchids. This latter pollination mechanism may have evolved in ice-front environments during the Pleistocene, but then became isolated to unusual partial analogues of ice-front habitat during the Holocene with pollination in most of the current range appearing to be a generalist strategy.

Key Words: *Cypripedium parviflorum* var. *pubescens*; *Packera paupercula*; *Osmia*; Large Yellow Lady's-slipper; Balsam Ragwort; pollination; mason bee; floral mimicry; Ontario; alvar

Introduction

The Large Yellow Lady's-slipper (*Cypripedium parviflorum* var. *pubescens* [Willdenow] Knight, previously recognized as *C. calceolus* L. var. *pubescens* [Willdenow] Correll) is reported to be pollinated by a variety of small bees (Argue 2012). Observations of only Mason Bees (*Osmia* spp.) pollinating the yellow, pollinator-rewarding Balsam Ragwort (*Packera paupercula* [Michaux] A. Löve and D. Löve) and the yellow, non-rewarding (i.e., deceptive) Large Yellow Lady's-slipper in the Ottawa Valley led to consideration of the extent to which the orchid may be an example of localized Batesian floral mimicry, where a species with non-rewarding flowers has evolved floral characteristics of a rewarding species that confer an advantage of increased pollinator visitation (Dafni 1984).

Floral mimicry has been reported in a number of orchids (e.g., Dafni and Irvi 1981; Gigord *et al.* 2002; Pellegrino *et al.* 2008; Edens-Meier *et al.* 2014) and in some Asian species of *Cypripedium* (Sugiura *et al.* 2002; Li *et al.* 2006) and has been recently inferred in the North American Ram's-head Lady's-slipper (*Cypripedium arietinum* R. Brown; Catling and Kostiuk 2013).

For Large Yellow Lady's-slipper and Balsam Ragwort to be an example of Batesian floral mimicry, five criteria discernible in field study should be considered, apart from the fact that the Balsam Ragwort model and the orchid mimic occur locally together: (1) Mason Bees visiting the ragwort also visit the orchid; (2) Mason Bees are more frequent visitors to Balsam Ragwort than to other co-blooming plants so that a specific model is suggested; (3) Mason Bees are primary pollinators of the orchid, i.e., the primary insect group transferring orchid pollen from one flower to another; (4) the behaviour of Mason Bees on the orchid flowers suggests mimicry; and (5) the orchid achieves higher abundance in the presence of Balsam Ragwort than in its absence, due in part to higher fecundity.

The present work focuses on the first four criteria listed above and considers support for the fifth. The work is centred on alvar landscapes in the Ottawa Valley that are diverse, rich in restricted species, and contain globally imperiled ecosystems (Catling 1995).

Study Area

The three study areas, all in eastern Ontario, included Marlborough Forest (45.0818°N, 75.8099°W), Braeside Alvar (45.4864°N, 76.4544°W), and Burnt Lands Alvar (Burnt Lands Provincial Park: 45.2530°N, 76.1486°W). The latitudes and longitudes represent approximate locations, and all observations and collections were made within 1 km of these sites. The specific study areas at each site were approximately 2 ha in extent and included 200–300 plants of Large Yellow Lady's-slipper and 200–700 plants of Balsam Ragwort. Large populations of Large Yellow Lady's-slipper occurred in the surrounding area, including up to 1000 plants within an area of 1 km^2. All three sites were dominated by more or less open woodlands of Eastern White Cedar (*Thuja* *occidentalis* L.) with some Balsam Fir (*Abies balsamea* [L.] Miller) and White Pine (*Pinus strobus* L.).

Methods

Gathering pollination data and voucher specimens

I gathered data by direct observation and collection of bees on orchid and ragwort flowers. On all days when observations of pollinators were made it was sunny and 20–24°C. Areas where pollinators were observed or collected were less than 0.4 ha in extent.

Examining bees reveals pollination because the adhesive pollen of the orchid flower is smeared onto the dorsal surface of the thorax as the bee leaves one of the basal side openings of the flower and can be seen on the insect's thorax for several days afterward (personal observation) indicating that it was at least a visitor to a Large Yellow Lady's-slipper flower and a potential pollinator.

Bees with *Cypripedium* pollen smears in the study areas were assumed to be pollinators of Large Yellow Lady's-slipper. Although Ram's-head Lady's-slipper is present and blooms at the same time (or starts slightly earlier), robust bees (such as Mason Bees) that are over 8 mm long are likely too large to enter and exit the flowers of that species and have not been implicated in its pollination (Catling and Kostiuk 2013). The pollen of these two orchids cannot be differentiated by simple light microscopy using a double-staining technique with phloxine and methyl green (personal observation).

Specimens of bees collected as part of this study are in the collection of Dr. Laurence Packer at York University, Toronto, Ontario, Canada, and that of Dr. Cory Sheffield at the Royal Saskatchewan Museum, Regina, Saskatchewan, Canada. Dr. Sheffield identified *Osmia subaustralis* Cockerell, 1900 and *O. albiventris* Cresson, 1864 and Dr. Anna Taylor identified *Osmia proxima* Cresson, 1864.

Mason Bees visiting the orchid as well as the ragwort

On both 1 and 2 June 2011, I spent approximately an hour observing pollination of Balsam Ragwort in a patch of 400 plants at Braeside. On 3 and 4 June 2011, I observed a group of approximately 600 plants of Balsam Ragwort for approximately 1.5 h on the Burnt Lands. In all cases, ragwort flowers were within 100 m of Large Yellow Lady's-slipper plants. Observations were made between 11 a.m. and 12:30 p.m. I collected and examined bees visiting Balsam Ragwort for orchid pollen smears on the dorsal thorax and released them at the end of the observation period.

Mason Bees visiting other co-blooming plants

On 9 May and 1 and 2 June 2011, at each of the three study sites, I spent an hour between 10 a.m. and 2 p.m. determining whether Mason Bees were visiting the only other species blooming in the area: the introduced Common Dandelion (*Taraxacum officinale* F. H. Wiggers), Swamp Dandelion (*T. palustre* [Lyons] Symons), and Wild Strawberry (*Fragaria virginiana* Miller).

Mason Bees, the primary pollinator of the orchid

On 29 May 2011, I attempted to observe pollinators at Braeside. I spent 3 h watching a group of 30 flowers of Large Yellow Lady's-slipper during sunny, mild weather between 11 a.m. and 2 p.m. On 2 and 11 June 2008, I spent 2 h each at Marlborough Forest and the Burnt Lands observing pollination in a group of 25 and 50 flowers, respectively.

Behaviour of Mason Bees suggesting mimicry

On 4 June 2011, between 9 a.m. and noon, I conducted eight experiments with three *Osmia subaustralis* (one male, two females) and five unidentified *Osmia*. The bees had been isolated and maintained in captivity, resting at low light and low temperature (20°C) for 20 h. As a result of their inactivity, they were each easily transferred into a fine mesh cage containing two fresh flowers of Large Yellow Lady's-slipper. The 16 orchid flowers selected for the observations had lips 31–40 mm long with more or less circular distal openings with a maximum width of 8–11 mm (Figure 1) and showed no signs of visitation in the form of scales, hairs or displaced pollen. The maximum width of basal open-

FIGURE 1. *Osmia proxima* Cresson, 1864 exiting one of the basal lateral openings of a flower of Large Yellow Lady's-slipper (*Cypripedium parviflorum* var. *pubescens* [Willdenow] Knight). The anther is on top of the thorax of the bee. Photo by P. M. Catling, Burnt Lands Provincial Park, 11 June 2008.

ings was 2–3 mm becoming 3–5 mm when the lip was pressed downward. The flower stems were placed upright in water in a coffee cup, through a small opening in the lid; this prevented bees from falling into open water. Observations were made through the glass front after strong light and heat rising to 24°C was focused on the cage and led to activity. An experiment was considered to be completed when a bee became inactive or when it appeared intent on escape and showed little interest in the flowers.

Results

Of 76 bees captured while they were visiting Balsam Ragwort, 25 carried pollen likely originating from Large Yellow Lady's-slipper (Table 1).

Both co-blooming dandelion species were past peak flowering and infrequent. Wild Strawberry was infrequent but in peak bloom locally. Although many bees were seen on the flowers of these plants only one Mason Bee was seen visiting them — a flower of Wild Strawberry.

All observations of pollination are summarized in Table 2, which includes seven pollinator and three visitor records, all of which involved Mason Bees. In most cases, the bees were captured after they left one flower and entered another; they were removed from the second flower. Apart from the fact that flowers were entered within a few seconds, there were no detailed observations of behaviour, except in the following two cases.

At Burnt Lands Alvar on 11 June 2008 on a sunny morning with air temperature 18°C, a bee was found inside the lip of a Large Yellow Lady's-slipper flower. The plant was covered with a net and within five minutes the bee exited the flower from a lateral basal opening with pollen on the thorax (Figure 1). It was later identified as *Osmia proxima*.

At Marlborough Forest on 2 June 2008 on a sunny late afternoon with air temperature 22°C, after a cloudy morning, a bee landed on the staminodium of a Large Yellow Lady's-slipper flower, then fell into the lip cavity. It emerged seven minutes later, with much pushing downward of the lip, from a lateral opening with pollen on its back. It was later identified as *Osmia proxima*.

During experiments to investigate mimicry, the bees generally became active within 10 minutes and flew around inside the cage. Within 1–18 minutes of flight, nine of ten bees landed on the staminodium of a centrally located Large Yellow Lady's-slipper flower. They then turned back and forth over the staminodium

TABLE 1. Observations of Mason Bees (*Osmia* spp.) carrying pollen of Large Yellow Lady's-slipper (*Cypripedium parviflorum* var. *pubescens* [Willdenow] Knight).

No. of bees with pollen (total bees observed)	Location	Collected on/in	Date
5 (20)	Braeside	Balsam Ragwort (*Packera paupercula* [Michaux] A. Löve and D. Löve)	1 June 2011
9 (20)	Braeside	Balsam Ragwort	2 June 2011
5 (20)	Burnt Lands	Balsam Ragwort	3 June 2011
6 (16)	Burnt Lands	Balsam Ragwort	4 June 2011

TABLE 2. Observations of Mason Bees (*Osmia* spp.) pollinating or visiting Large Yellow Lady's-slipper (*Cypripedium parviflorum* var. *pubescens* [Willdenow] Knight).

Bee species	Location/origin	Notes	Date
1 *Osmia proxima* Cresson, 1864	Burnt Lands	Pollinator. Found inside lip, exited with pollen.	11 June 2008
1 *Osmia* sp.	Burnt Lands	Pollinator. Leaving flower with pollen and entering another.	11 June 2008
1 *Osmia* sp. with pollen.	Marlborough 3 June 2008	Visitor, leaving flower	
1 *Osmia proxima* Cresson, 1864	Marlborough	Pollinator. Landed on staminodium with pollen then exited flower with pollen.	3 June 2008
2 cf. *Osmia albiventris* Cresson, 1864 (male)	Braeside	Pollinators. Both visiting two consecutive flowers with pollen taken to both flowers.	29 May 2011
3 *Osmia subaustralis* Cockerell, 1900 (1 female, 2 males)	Braeside	Pollinators. All three visiting two consecutive flowers with pollen taken to both flowers.	29 May 2011
1 *Osmia* sp.	Braeside	Visitor. Visiting a single flower and emerging with pollinia.	29 May 2011

probing it actively with the tongue. After 15–120 seconds of this, all nine bees fell off the staminodium into the lip. Time to exit was usually 5 minutes, but was 35 minutes in one case. In a few instances, a bee was inactive inside the lip for 5–10 minutes. Time spent struggling in the exit area below the stigma was 3–10 minutes and, during this time, the bee often pushed the lip downward, evidently with its back against the column to increase the space. Once the bee's head had reached the side opening, exit from the flower, as it passed under the stamen, required only 2–7 seconds. This was true for seven of nine trapped bees. Of the other two, one exited the side opening upside down with pollen attaching to the underside of the thorax and abdomen. Another bit a hole through one of the windows at the base of the lip and exited that way within 9 minutes after entering a flower. Most bees spent a few minutes grooming after leaving the flower and one had the wings stuck together, with pollen, over the back. Two bees went to, and through, the second flower within 5 minutes of visiting the first.

Discussion

The number of bees visiting Balsam Ragwort that carried pollen of Large Yellow Lady's-slipper seemed high, based on low levels of capsule development in many areas suggesting low levels of insect visitation. However, the orchid was common in both areas (Braeside and Burnt Lands) and generally flowered a little earlier than Balsam Ragwort; thus, it may have attracted attention when resources were limited.

Although the survey of Mason Bees on co-blooming plants included over 2 h of observation time, this is not considered an extensive survey. Nevertheless, it provides evidence that Mason Bees were very much associated with Balsam Ragwort and less so with other flowering plants.

The 11 observations of Mason Bees and no other species of bees on Large Yellow Lady's-slipper is evidence that they were the primary pollinators at these study locations (Braeside and Burnt Lands alvars and Marlborough Forest). Although Mason Bees were the only pollinators in the present study, studies of the similar, although not closely related (Li *et al.* 2011), European Lady's-slipper Orchid (*Cypripedium calceolus* L.) have revealed a number of different bee pollinators (Nilsson 1978, Antonelli *et al.* 2009). For Large Yellow Lady's-slipper in eastern North America, the only pollinators reported are halictid bees and small Carpenter Bees (*Ceratina* spp.), and these were based on few records (Argue 2012). I saw bees from both of these groups in the study areas and a significant bee fauna was present at least at the Burnt Lands site (Taylor and Catling 2011), although not all of these species would be active at the time of blooming of the orchid. Many species of bees, including Mason Bees, have been reported as visitors to Large Yellow Lady's-slipper (Argue 2012). Although this suggests that many bee species may be involved in its pollination and some regional variation may be anticipated, Mason Bees may be the primary pollinators in some of the larger orchid populations in the study areas.

The pollination of slipper orchids is based on control of the path of the insect through the flower by morphologic attributes of the flower lip, where the insect enters the large frontal opening, deposits pollen, picks up a new pollen load, and then exits by one of the two small openings on either side of the lip base (Figure 1). This well-known and accepted phenomenon was first elaborated by Darwin (1862), but more correctly and in more detail in Darwin (1877) following help from Asa Gray, and it was later discussed by many others (e.g., Stoutamire 1967; Catling and Catling 1991; Argue 2012). What has been controversial is the attractant. Ideas have varied: the food value of hairs on the inner lip, the production of fragrances by the pollinating bees, the resemblance of the lip to a cavity nest site, and general food deception involving colour and nectar guides (Catling and Catling 1991; van der Cingel 2001). The latter of these has been the most agreed upon, but an interesting addition is that a flower may be more likely to be visited again if it has already been visited, as a result of accumulation of bee odours on specialized hairs (Nilsson 1978). The present work supports food deception, but further suggests that Mason Bees may be specifically attracted to the staminode due to its resemblance to the centre of a *Packera* flower. The darker and orange areas in open disc flowers within a mass of yellow disc flowers in Balsam Ragwort are similar to orange spots on a yellow staminodium of similar size in the orchid. The only other case in *Cypripedium* where bees contacted the staminodium first before falling into the labellum involved *C. guttatum* Swartz and mimicry was not implicated (Bänziger *et al.* 2005).

A distribution map for Balsam Ragwort in Ontario (Catling 1995, Figure 7) indicates a concentration in alvar landscapes along the edges of the Canadian Shield. Similarly, a map for Large Yellow Lady's-slipper (Whiting and Catling 1986, map 3c) shows concentrations in the same regions and absences from the Canadian Shield and parts of southwestern Ontario. Although the orchid is more widespread than the ragwort, it is similarly associated with limestone rock (Whiting and Catling 1986). The areas of high abundance of the orchid in southern Ontario are well known and include Manitoulin Island, the Bruce Peninsula, and limestone landscapes near Kingston and Ottawa. For example, with regard to the Bruce Peninsula, the Bruce-Grey Plant Committee (1997) notes that "it may be more common [here] than in any other part of Ontario." These same landscapes are the areas of abundance of Balsam Ragwort.

Conclusions

The following observations support the case for Batesian floral mimicry. A large proportion of Mason Bees visiting Balsam Ragwort also visited the orchid.

but not other co-blooming flowers. Mason Bees were the primary pollinators of the orchid and behaved on the orchid flowers as they did on the flowers of Balsam Ragwort by landing on the staminodium, which resembles the centre of the ragwort flower. Orchids were more abundant where the ragwort was abundant. Although it may be appropriate to consider ragwort species as important models in a generalized magnet species effect, pollination may vary geographically from non-model to species-specific Batesian mimicry where a single model can be readily identified. This latter possibility is of interest for three reasons: the rarity of floral mimicry in orchids, the existence of specialist and generalist strategies within one taxon, and the possibility of early evolution and mimicry in the past.

Floral mimicry is rare in orchids

Members of the genus *Cypripedium* have generally been regarded as generalist (non-model) food mimics (Catling and Kostiuk 2006; Pelligrino *et al.* 2008) like most food-deceptive orchids, which include a third of all orchids (Cozzolino and Widmer 2005), the largest family of vascular plants. Most deceptive orchids have not evolved species-specific Batesian floral mimicry (Johnson *et al.* 2003; Li *et al.* 2006), although it has been attributed to various species around the world, including Red Helleborine (*Cephalanthera rubra* [L.] Richard) from Europe (Nilsson 1983), Leopard Orchid (*Diuris maculata* Smith) from Australia (Beardsell *et al.* 1986), and Cluster Disa (*Disa ferruginea* [Thunb.] Swartz) from South Africa (Johnson 1994). Mimicry has been reported only recently in two of approximately 50 species of *Cypripedium*, a genus of the northern hemisphere (Li *et al.* 2011): a Japanese Lady's-slipper (*C. macranthos* Sw. var. *rebunense* (Kudo) Miyabe & Kudo (Sugiura *et al.* 2002) and Ram's-head Lady's-slipper (*C. arietinum* R. Brown) (Catling and Kostiuk 2013).

A specialist and a generalist within one taxon

Geographically based differences in food deception within taxa, ranging from specialization to generalist strategies, may be more frequent than is realized. The idea of such micro-ecological isolating mechanisms is not new and was discussed by Heslop-Harrison (1958) with regard to orchids and by Stoutamire (1967) with regard to lady's-slippers. This within-taxon variation may not always be as obvious as the anomalous white-flowered var. *rebunense* of *Cypripedium macranthos* on Rebun Island, Japan, which visually mimics the white-flowered *Pedicularis schistostegia* Vvedensky (Sugiura 2001, 2002). The pollinator-mediated mating restriction that has been shown between the varieties of *C. parviflorum* (Case and Bradford 2009; Case and Bierbaum 2013) may also occur between geographic races. There is also evidence for different pollination races in European *C. calceolus* (Antonelli *et al.* 2009). That different pollination races exist in Large Yellow Lady's-slipper is suggested by the 36 records of visitation and pollination by Mason Bees on alvar landscapes and no records of other bees, as reported here, compared with reports of many other kinds of visiting bees in other locations (van der Cingel 2001). The possibility that some lady's-slipper species, and other deceptive orchids, are both specialists and generalists requires more study.

Early evolution and mimicry in the past

Mimicry might have originated as a general resemblance to co-occurring floral food sources, such as yellow blossoms. Although similar colours may not always indicate mimicry or pollinator sharing (Bierzychudek 1981), they might. Supporting this is the observation of the unusual abundance of Large Yellow Lady's-slipper (thousands of plants in a few hectares) along with several co-blooming, yellow-flowered species in remnant prairies along the railway lines in southeastern Saskatchewan (Catling and Kostiuk 2006). Corolla colour is sufficient to achieve floral mimicry, and pollinators can select for it (Gigord *et al.* 2002). Yellow-flowered species prominent in the Saskatchewan prairies are Hoary Puccoon (*Lithospermum canescens* [Michaux] Lehmann) and Heart-leaved Alexanders (*Zizia aptera* [A. Gray] Fernald), but species of ragwort are also present (personal observation). Following development of colour resemblance, the orchid may have evolved a more specific resemblance to Balsam Ragwort by developing reddish spots on the staminode and possibly in other ways. This may have occurred in the open, ever-changing ice-front environments that lasted for many thousands of years during the Pleistocene.

More recently, during the Holocene, the mimetic pollination system may have become isolated to unusual partial analogues of ice-front habitat with pollination in most of the current range appearing to be a generalist strategy. Thus we have a Batesian mimic that to a large extent became a generalist with only localized situations, as in the alvars studied here, that make the former pollination mechanism clear. Certainly, within the general range, there are areas of high abundance of Large Yellow Lady's-slipper, and many of these are in places that resemble ice-front and early postglacial habitats, such as alvars (Catling and Brownell 1995). Regardless of the likelihood of this hypothesis, it does draw attention to the possibility that pollination in temperate plants may sometimes be better understood through reference to past conditions.

Future research

Although this articles presents evidence to suggest Batesian floral mimicry, the suggestion would be strengthened if the bees were found to carry only ragwort pollen, rather than observing bees visiting only ragwort flowers, as sampling based on a longer period would be achieved in this way.

Two more protocols for data collection that can be considered in future studies are: (1) flowers of the orchid and ragwort can be compared under ultraviolet (UV) light to determine whether similar patterns exist, although floral mimicry is not entirely dependent on UV reflectance (Gigord *et al.* 2002); and (2) a biochemical analysis of scent would be helpful to determine the extent to which that factor plays a role, although studies have suggested that visual attributes may be more important than scent chemistry in deceptive orchids (Jersáková *et al.* 2012). The scent components may be general or contain those of the ragwort or even those of the pollinating bees (Volterová *et al.* 2007). These protocols have been effectively applied to studies of Batesian floral mimicry in other species (Edens-Meier *et al.* 2014).

Acknowledgements

Dr. Cory Sheffield and Dr. Anna Taylor assisted with identification of bees. Dr. Peter Bernhardt provided helpful advice.

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Received 21 March 2014
Accepted 18 May 2014

Gastony's Cliffbrake (*Pellaea gastonyi*) in Manitoba: New Records and Assessment of Conservation Status

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Friesen, Chris, and Colin Murray. 2015. Gastony's Cliffbrake (*Pellaea gastonyi*) in Manitoba: new records and assessment of conservation status. Canadian Field-Naturalist 129(1): 45–52.

Gastony's Cliffbrake (*Pellaea gastonyi* Windham) is a globally rare fern (Pteridaceae) that grows on limestone cliffs and ledges, including those associated with alvars. Until now, the only record in Manitoba was from a location just north of Fisher Branch. We report additional records and locations, one of which is over 250 km north of the initial collection. We also provide a conservation status assessment of this species in Manitoba that indicates that this species is rare in the province and is threatened in a least a portion of its range by habitat loss and degradation.

Key Words: Gastony's Cliffbrake; *Pellaea gastonyi*; Manitoba; limestone; alvar; rare species; fern; habitat loss

Gastony's Cliffbrake (*Pellaea gastonyi* Windham) is a fern (Pteridaceae) of calcareous outcrops and cliffs (Windham 1993a). Its distribution consists of scattered occurrences in central and western North America (Windham 1993b), including South Dakota, Wyoming, Missouri, and Washington in the United States (Windham 1993b; Rocky Mountain Herbarium 2008). Aside from Manitoba, its Canadian range includes the cordilleran regions of British Columbia and Alberta and a disjunct population in northern Saskatchewan (Rigby and Britton 1970; Windham 1993a). The global conservation status of Gastony's Cliffbrake is G2G3 – Imperilled–Vulnerable (NatureServe 2013), although it may be locally abundant (Brunton 1979).

The species arose through hybridization of apogamous triploid Purple-stemmed Cliffbrake (*Pellaea atropurpurea* [L.] Link) and diploid Western Dwarf Cliffbrake (*Pellaea glabella* ssp. *occidentalis* [E. E. Nelson] Windham), except for Missouri material, which has the diploid *Pellaea glabella* ssp. *missouriensis* (Gastony) Windham as a parent (Gastony 1988; Windham 1993a). Because the hybrid is apogamous and, thus, able to reproduce autonomously from the parent taxa, it was described as a new species by Windham (1993a). Of the parent taxa, only Western Dwarf Cliffbrake occurs in Manitoba, where scattered populations are known from the southern half of the province, and plants are often locally abundant where suitable habitat, i.e., calcareous outcrops, exists (Manitoba Conservation Data Centre, unpublished data). The sparsely villous rachis and purple-brown petiole of Gastony's Cliffbrake reliably distinguish it in the field from Western Dwarf Cliffbrake which has a hairless rachis and a light-brown to straw-coloured petiole (Windham 1993a; Harms and Leighton 2011). It is distinguished from Purple-stemmed Cliffbrake by the presence of long, divergent (versus more abundant short, curly) hairs along the rachis, smaller ultimate leaf segments, and large spores (Windham 1993a).

The first Manitoba collection of Gastony's Cliffbrake (MANITOBA: South side of Marble Ridge Road, 1.6 km west of its junction with Highway 17, about 12 km north of Fisher Branch, 51.18361°N, 97.62556°W, dolomite cliff face, 26 July 2001, *B. A. Ford 0140, M. Piercey-Normore & D. Punter*, WIN 67479; D. F. Brunton herbarium) has not been previously reported in the literature. It was initially identified as Smooth Cliffbrake (*Pellaea glabella* Mettenius ex Kuhn), then annotated to Gastony's Cliffbrake by D. F. Brunton in 2005. Western Dwarf Cliffbrake is also present at this location (Manitoba Conservation Data Centre, unpublished data). The specimen was collected at the north end of a limestone outcrop, locally known as Marble Ridge, which extends approximately 20 km to the southeast. The north end of Marble Ridge has been of ecological interest for some time because of its near-surface limestone bedrock and limestone cliffs, and it is now recognized as an alvar ecosystem (Neufeld *et al.* 2012). Until the surveys reported here, the population at this location was the only one known in Manitoba.

Study Area and Methods

Near-surface limestone bedrock occurs in large areas of Manitoba's Interlake region, and alvars are known to occur in several of these areas (Manitoba Conservation Data Centre, unpublished data). In 2012, the Manitoba Conservation Data Centre (MBCDC) partnered with the Nature Conservancy of Canada to conduct surveys in the southern portion of the Interlake to determine the extent and quality of alvar ecosystems and limestone cliffs in this region and record observations of rare plant taxa, including *Pellaea* Link species (Neufeld *et al.* 2012). Additional surveys of limestone-dominated areas near Grand Rapids in the northern portion of the Interlake were conducted in 2012 and 2013 by MBCDC staff. Because Scoggan (1957) reported Western Dwarf Cliffbrake at Grand Rapids, the MBCDC surveys focused on limestone cliffs and ledges in an effort to refine the known distribution of this species in the area and search for Gastony's Cliffbrake.

For the Manitoba Alvar Initiative, 67 candidate survey sites were identified using aerial imagery and GIS shapefiles of geological data available through the Manitoba Land Initiative (http://mli2.gov.mb.ca/) and 61 of these sites were surveyed in 2012 (Neufeld *et al.* 2012). For surveys at Grand Rapids, reports from the Manitoba Geological Survey (Bezys and Kobylecki 2003; Kobylecki and Bogdan 2004) were also used to identify potential survey sites. Additional sites were identified in the field while conducting surveys. At Grand Rapids, seven sites were surveyed in 2012. In 2013, five new sites were surveyed and additional surveys were carried out at one 2012 site. The locations of *Pellaea* species were recorded with a Global Positioning System (GPS) unit and specimens were collected when necessary for confirmation of identification or to document new locations. All specimens were deposited at the University of Manitoba Herbarium (WIN). Habitat type and condition were noted, and a coarse visual estimate of the number of plants was made. All known Manitoba occurrences of Gastony's Cliffbrake are shown in Figure 1.

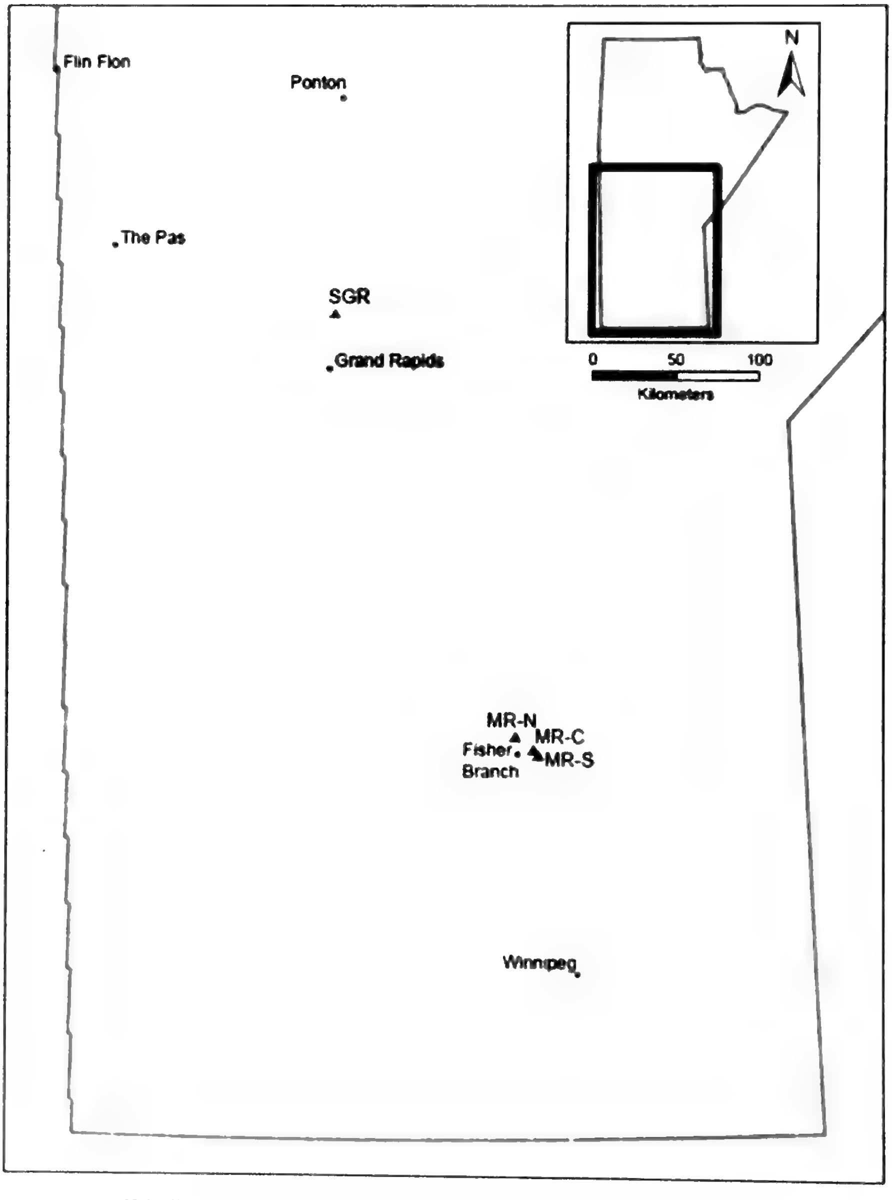

FIGURE 1. *Pellaea gastonyi* Windham) locations (black triangles) in Manitoba. Note: MR-N, C, S = Marble Ridge North, Centre, and South, respectively; SGR = Sturgeon Gill Road.

Results

Marble Ridge North

This site corresponds to the location of the first Manitoba collection of Gastony's Cliffbrake (see Introduction); thus, no additional specimens were collected during the surveys reported here. In 2012, surveys expanded the areal extent of the known population of Gastony's Cliffbrake at the north end of Marble Ridge from approximately 1.3 ha to 148 ha. The population size was estimated to be 300-500 plants. The actual extent of this occurrence and number of plants may be somewhat larger as additional suitable habitat in the area remains to be surveyed. Most of the northern portion of Marble Ridge is alvar, with limestone bedrock at or within several centimetres of the surface. There are numerous limestone outcrops and plateaus up to 2 m high on the alvar, and it was at the edges of these outcrops, in the cracks in the limestone, that Gastony's Cliffbrake was most often observed (Figure 2). The limestone at the edges of the outcrops tended to be more fractured and less consolidated than limestone elsewhere in the alvar. Gastony's Cliffbrake was also observed growing at the base of limestone boulders sitting on the alvar (Figure 3). It was only observed in areas of full or part sun. Western Dwarf Cliffbrake was also frequently observed in the area, although it was most often found growing in horizontal cracks in vertical faces of limestone cliffs and boulders, sometimes in very shaded areas.

Marble Ridge Centre

In 2012, a new location of Gastony's Cliffbrake was discovered in the central portion of Marble Ridge (MANITOBA: NW25-24-01W1, 51°06'30"N, 97°28'53"W, small cliff limestone ledge, 6 July 2012, *Chris Friesen MBCDC9*, WIN 76794), approximately 12 km southeast of Marble Ridge North. The areal extent of occurrence was approximately 3.3 ha with an estimated population size of fewer than 100 plants. This area is also alvar and, as at Marble Ridge North, Gastony's Cliffbrake was found growing in open areas at the edges of limestone outcrops in cracks in the rock. This portion of Marble Ridge contains additional unsurveyed habitat that likely supports Gastony's Cliffbrake. Western Dwarf Cliffbrake was also found in the area, but only on shaded cliff faces.

FIGURE 2. Limestone ridge on Marble Ridge alvar similar to those that support Gastony's Cliffbrake (*Pellaea gastonyi* Windham). Photo courtesy of the Nature Conservancy of Canada, 2012.

FIGURE 3. Limestone boulders on Marble Ridge alvar, some of which support Gastony's Cliffbrake (*Pellaea gastonyi* Windham). Photo courtesy of the Manitoba Conservation Data Centre, 2012.

Marble Ridge South

Approximately 4.5 km southeast of Marble Ridge Centre, another population of Gastony's Cliffbrake was discovered in 2012 (no specimen collected). This population was divided between two limestone outcrops separated by a 200-m wide wooded gully. The population consisted of fewer than 100 plants in a very small area (approximately 0.04 ha) on the west side of the gully, with one additional plant found on the opposite side of the gully. The outcrops on either side of the gully were open alvars. The plants on the west side were growing in habitat similar to those found at Marble Ridge North and Marble Ridge Centre. The one plant found on the east side of the gully was growing in deep shade on the edge of the outcrop. This was the only location where Gastony's Cliffbrake was found growing in shade.

Vegetative cover at the Marble Ridge sites was dominated by lichens and mosses growing on limestone bedrock and low-growing vascular plants including Creeping Juniper (*Juniperus horizontalis* Moench), Common Bearberry (*Arctostaphylos uva-ursi* [L.] Sprengel), and Poverty Oatgrass (*Danthonia spicata* [L.] P. Beauvois ex Roemer & Schultes).

Grand Rapids, Sturgeon Gill Road

Many of the 12 Grand Rapids sites surveyed had apparently suitable habitat for Gastony's Cliffbrake, but it was found at just one (MANITOBA: 53°28′49″N, 99°13′15″W, upper edge of limestone cliff, 21 September 2012, *C. Friesen MBCDC72*, WIN 76797). This site, which is just north of Sturgeon Gill Road, approximately 32 km north of Grand Rapids, was first surveyed in 2012 with additional surveys in 2013. Over the 2 years, up to 100 plants were found growing at the top of a limestone cliff in cracks in the limestone bedrock (Figure 4). Near-surface limestone bedrock was commonly observed near Grand Rapids, and such areas were usually dominated by Jack Pine (*Pinus banksiana* Lambert) and Paper Birch (*Betula papyrifera* Marshall). The Gastony's Cliffbrake site was a Jack Pine–Paper Birch stand with sparse to discontinuous tree cover (Figure 5). The limited tree cover was likely because of the lack of soil and the fire history of the site; the most recent burn was in 1979 (Manitoba 2013). Western Dwarf Cliffbrake was observed at this and a number of other sites near Grand Rapids, typically growing in the horizontal cracks of limestone cliffs.

FIGURE 4. Limestone ledge habitat of Gastony's Cliffbrake (*Pellaea gastonyi* Windham) north of Grand Rapids, Manitoba. Photo courtesy of the Manitoba Conservation Data Centre, 2012.

FIGURE 5. Jack Pine–Paper Birch habitat on near-surface limestone bedrock near Grand Rapids, Manitoba. Photo courtesy of the Manitoba Conservation Data Centre, 2012.

Discussion

Brunton (1979) noted that in Alberta there was a clear association between site orientation and the *Pellaea* taxa present. Sites supporting Gastony's Cliffbrake in Manitoba are level or have only slight directional orientation and are in full to part sun; only one plant (at Marble Ridge South) was found growing in the shade of adjacent vegetation. Plants in Missouri are also found in full sun (G. Yatskievych, curator, Missouri Botanical Garden, 10 January 2014, personal communication). Western Dwarf Cliffbrake was found in both open areas and those shaded by adjacent vegetation (e.g., trees growing immediately adjacent to cliff face at Marble Ridge North).

Many sites surveyed included apparently suitable habitat (exposed fractured limestone), yet supported few, if any, Gastony's Cliffbrake. The paucity of Gastony's Cliffbrake at such sites may indicate that microhabitat or microclimatic characteristics are not suitable (Richard *et al.* 2000). Alternatively, factors related to dispersal and establishment could be limiting the small- to medium-scale distribution (Wild and Gagnon 2005).

At a broader scale, Gastony's Cliffbrake occurs in three ecozones in Canada: montane–cordillera (British Columbia and Alberta sites), boreal shield (northern Saskatchewan site), and boreal plains (Manitoba sites) (Ecological Stratification Working Group 1995). Its North American distribution ranges from the Great Plains (Missouri, South Dakota) in the south to the boreal forest near Lake Athabasca in northern Saskatchewan. These data suggest that, as a species, it is tolerant of considerable climatic variation at a broad scale.

The typical habitat for this species throughout its range is calcareous rock, often limestone or dolomite (Brunton 1979; Windham 1993a), and the discontinuous distribution of this substrate in North America likely accounts for the similarly discontinuous distribution of Gastony's Cliffbrake. Hastings (2002) linked the distribution of Grimmia Dry Rock Moss (*Grimmia teretinervis* Limpricht), a moss of calcareous rock that occurs at Marble Ridge and near Grand Rapids (Caners 2011; Manitoba Conservation Data Centre, unpublished data), to the margins of ancient epicontinental seaways, with occurrences in central and western North America associated with the margin of the Cretaceous epicontinental seaway. The known Canadian occurrences of Gastony's Cliffbrake occur near the margins of this seaway, suggesting that a more detailed review of the North American occurrences of this species and ancient seaway margins is warranted.

Distribution and search effort

Including the records reported here, the distribution of Gastony's Cliffbrake in Manitoba extends discontinuously from near Fisher Branch in the southern Interlake region to the Grand Rapids area in the northern Interlake (Figure 1). The total extent of occurrence in Manitoba, as calculated with a minimum convex polygon encompassing all known occurrences, is 1282 km^2, although much of this area is not suitable habitat. The indexed area of occupancy, using 1 km × 1 km and 2 km × 2 km grids, is 11 km^2 and 20 km^2, respectively (IUCN Standards and Petitions Subcommittee 2013). There are likely additional occurrences in Manitoba that remain to be discovered, especially in the northern Interlake. As noted above, many areas of near-surface limestone bedrock in the southern Interlake have been the subject of at least cursory surveys, and, given the apparently narrow habitat preference of Gastony's Cliffbrake, it seems unlikely that its known distribution in the southern Interlake will change significantly. Large areas of near-surface limestone bedrock, with associated cliffs and outcrops, remain unsurveyed in the northern Interlake. However, of 12 sites searched in 2012 and 2013 by the MBCDC, only one supported Gastony's Cliffbrake. Also, it has not been found during surveys in 2008 and 2013 of ferns associated with limestone north and west of the Interlake near Ponton, Flin Flon, and The Pas (R. Staniforth, professor (retired), University of Winnpeg, 11 January 2014, personal communication). These observations suggest that although apparently suitable habitat is common in the northern Interlake, the distribution of Gastony's Cliffbrake is likely limited. Thus, the overall known distribution of Gastony's Cliffbrake in Manitoba is unlikely to change dramatically with the discovery of additional populations.

Population size and trends

Detailed counts have not been conducted, but the coarse estimates reported here suggest that three of the four Manitoba occurrences consist of up to 100 plants. The largest occurrence, at the northern end of Marble Ridge, likely has up to 500 plants. Thus, in total, there are likely no more than 1000 plants known in Manitoba. Given the amount of potential habitat in Manitoba that remains to be surveyed, additional search effort may result in a moderate increase in the number of known plants.

Because the species was only recently discovered in Manitoba and surveys to date have focused on determining distribution rather than population size, it is not possible to determine trends in population size. The extent and condition of habitat appear relatively stable, which suggests a similar trend in population size. Some plants may have been destroyed by quarrying at the north end of Marble Ridge (Manitoba Conservation Data Centre, unpublished data).

Limiting factors and threats

Mining and forestry activities north of Grand Rapids may threaten this species. However, there is currently no mining or forestry activity within several kilometres of the Gastony's Cliffbrake site (Manitoba 2014; T. Werstroh, regional forester, Manitoba Conservation and Water Stewardship, 19 February 2014, personal communication).

Areas supporting Gastony's Cliffbrake have near-surface limestone and are, therefore, of interest to quarry operators, particularly at Marble Ridge. Several quarry leases at the north end of Marble Ridge include areas that support Gastony's Cliffbrake. Such areas would require protection if lease holders develop this land. Several existing quarries are in areas that likely supported alvar, and possibly cliffbrakes, before quarry development (Neufeld *et al.* 2012).

The portions of Marble Ridge that support this species are leased for cattle grazing. However, grazing and trampling are unlikely threats to Gastony's Cliffbrake as those areas produce little forage (Neufeld *et al.* 2012). Surveys in 2012 did not reveal any apparent damage to this species by cattle (Neufeld *et al.* 2012).

Current protection and status

Gastony's Cliffbrake is not protected under Manitoba's *Endangered Species and Ecosystems Act* or Canada's *Species At Risk Act*, nor has it been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). All known occurrences in Manitoba are on provincial crown land where certain uses and activities are regulated. As such, they may be protected from certain activities, although there are other resource claims, such as quarry leases, on some of this land (Neufeld *et al.* 2012).

The NatureServe global and Canadian national conservation status ranks for Gastony's Cliffbrake are both Imperilled–Vulnerable (G2G3 and N2N3, respectively); the species has not been ranked nationally in the United States (NatureServe 2013). In Canadian provinces, the status ranks are S1 in Alberta, Saskatchewan, and Manitoba and S2S3 in British Columbia (NatureServe 2013). Despite the additional populations and increased extent of occurrence reported here, the S1 rank for Gastony's Cliffbrake in Manitoba remains appropriate as the number of populations is small and the number of individuals is limited.

Acknowledgements

Support for the Manitoba Alvar Initiative was provided by Manitoba Conservation and Water Stewardship (MCWS), and Nature Conservancy of Canada (NCC). Support for surveys at Grand Rapids was provided by MCWS. NCC staff, Cary Hamel and Rebekah Neufeld, worked on the alvar project. Richard Staniforth, University of Winnipeg, retired, assisted with specimen identification and provided moral support for the surveys. He also reviewed the draft article and provided constructive comment, as did James Duncan of the Wildlife Branch of MCWS and two anonymous reviewers. Dan Brunton provided background information on the first Manitoba record and Diana Sawatzky, assistant curator, University of Manitoba Herbarium, provided label information for the specimens at the herbarium. Scott Foster, MCWS district supervisor, was a gracious host at the Grand Rapids bunk house.

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Accepted 6 May 2014
Received 7 November 2014

Subspecific Identification of the Great Lakes' First Brown Booby (*Sula leucogaster*) Using DNA

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Skevington, Jeffrey H., James Pawlicki, Scott Kelso, Kevin C. R. Kerr, and Marcie Jacklin. 2015. Subspecific identification of the Great Lakes' first Brown Booby (*Sula leucogaster*) using DNA. Canadian Field-Naturalist 129(1): 53–59.

The first Brown Booby (*Sula leucogaster*) recorded in the Great Lakes basin was discovered on Lake Erie near the source of the Niagara River on 7 October 2013 by J. P. Morphologic evidence suggested that this bird was an adult female of the nominate Atlantic subspecies. We obtained genomic DNA from feces left by the bird. Mitochondrial DNA from the control region (CR2) was sequenced and compared with extensive CR2 data for Brown Booby available in GenBank; this corroborated the morphologic hypothesis. This is the first time that a vagrant bird in Canada has been identified using DNA extracted from feces.

Key Words: Brown Booby; *Sula leucogaster*; Great Lakes; distribution; vagrant; mitochondrial DNA; mtDNA; new record; Ontario; DNA extraction; feces; fecal sample; DNA identification

Introduction

On 7 October 2013, J. P. discovered a Brown Booby (*Sula leucogaster*) on Lake Erie at the source of the Niagara River. This was the first time the species had been observed on the Great Lakes. The bird was most frequently observed with Double-crested Cormorants (*Phalacrocorax auritus*) at Donnelly's Pier (42.884485°N, 78.903401°W) on the Buffalo, New York, side of the lake and on the historic Horseshoe Reef Lighthouse just inside United States waters (42.881273°N, 78.915133°W) (Burrell 2013). The bird was regularly observed venturing far out into the open lake to feed and was often seen crossing over to the Ontario side. Eighty observations made from the Buffalo side of the Niagara River and 79 from the Fort Erie side were entered into eBird, which is an online platform for reporting bird checklists (Sullivan *et al.* 2009). Undoubtedly many more observations of the bird were made, but were not added to the database. The last known observation of the Brown Booby at this location was made on 24 October (Pawlicki 2014).

What was presumably the same bird (based on the sex, age, and facial markings) was rediscovered 99 km to the southwest at the tip of Long Point, Ontario (42.549816°N, 80.043848°W) on 31 October by Ken Burrell (Pawlicki 2014). It was seen again at that location on the morning of 1 November before being rediscovered in the afternoon 55 km to the northeast at Mohawk Point, Ontario (42.849085°N, 79.467712°W). It was last seen on 2 November 2013 at Mohawk Point, when observers noted that it looked moribund (Jacklin 2013; Watson 2013). J. H. S. requested feathers or tissues if the bird succumbed (Jacklin 2013); however, it revived and disappeared out over the lake (D'Anna and Potter 2013). It was never seen again but M. J. collected fecal samples from where the bird had been sitting and sent them to J. H. S. for analysis. The fecal samples were easy to isolate, as they were the only excrement on the rock where the booby had been sitting. The samples were collected with a cotton swab and sealed into a zip-lock bag.

There are four recognized subspecies of Brown Booby (Schreiber and Norton 2002). Brewster's Brown Booby (*Sula leucogaster brewsteri*) breeds in the Gulf of California; Columbian (*S. l. etesiaca*) breeds along the Pacific coast from Honduras to Colombia; Forster's (*S. l. plotus*) breeds across the central, west and southern Pacific Ocean; and the nominate Atlantic (*S. l. leucogaster*) breeds in the tropical Atlantic from the Bahamas and Caribbean to the Central American coast east to Cape Verde Island. In a typical year, any east-coast vagrant Brown Booby would be assumed to be the nominate subspecies. However, an unprecedented northward influx of Brown Boobies and Blue-footed Boobies (*Sula nebouxii*) along the Pacific coast (eBird 2013), combined with Ontario's first record of another Pacific coastal species (Elegant Tern, *Thalasseus elegans*) later in the autumn (20–24 November 2013; eBird n.d.) led to speculation that the Lake Erie Brown Booby might have been from the eastern Pacific subspecies *brewsteri*.

Brown Boobies wander extensively away from their breeding islands but tend to stay in tropical waters (Schreiber and Norton 2002). There are scattered records from up the east coast as far as Nova Scotia and up the west coast to British Columbia, but only five previous inland records in eastern North America and no previous observations in the Great Lakes basin (Sullivan *et al.* 2009). Of note, four of these five inland records occurred in the past year. The inland records are from Claytor Lake, Pulaski County, Virginia, 4–28 October 2008; White Lake Wildlife Management Area, Warren County New Jersey, 27–31 July 2012; Lake Norrell, Saline County, Arkansas, 9–21 August 2012; and Canyon Lake, Comal County, Texas, 25 August to 3 September 2012 (Pawlicki 2014). Figure 1 shows these records on a map along with all eBird Brown Booby records (Sullivan *et al.* 2009). Records from 2012 and 2013 are shown in a different colour to illustrate the apparent upsurge in recent vagrancy.

From its clean brown and white plumage, it was apparent that the Great Lakes bird was an adult and, from the yellowish face and gular with an isolated dark blue loral spot, a female (Figure 2; Pyle 2008). Pyle (2008) also states that females of *S. l. leucogaster* show a pale bluish iris and the brown head and breast slightly darker or more blackish than the back, whereas *S. l. brewsteri* has a pale yellowish iris with the brown head and neck slightly paler and grayer than back. Before Pyle (2008) published these characteristics, it was generally believed that field identification of Brown Booby females to subspecies was impossible (Schreiber and Norton 2002). The characteristics are subtle and have not been tested adequately in the field. Based on photos and field observations, Pawlicki (2014) stated that the Great Lakes bird "appears to represent the nominate Atlantic subspecies."

FIGURE 2. Adult female Brown Booby (*Sula leucogaster*) sitting on Donnelly's Pier, Buffalo, New York, 9 October 2013. Photo by James Pawlicki.

In this paper we provide molecular evidence supporting this contention. Note that all four of the recent inland eastern North American records were believed to be of nominate adult female birds (Pawlicki 2014).

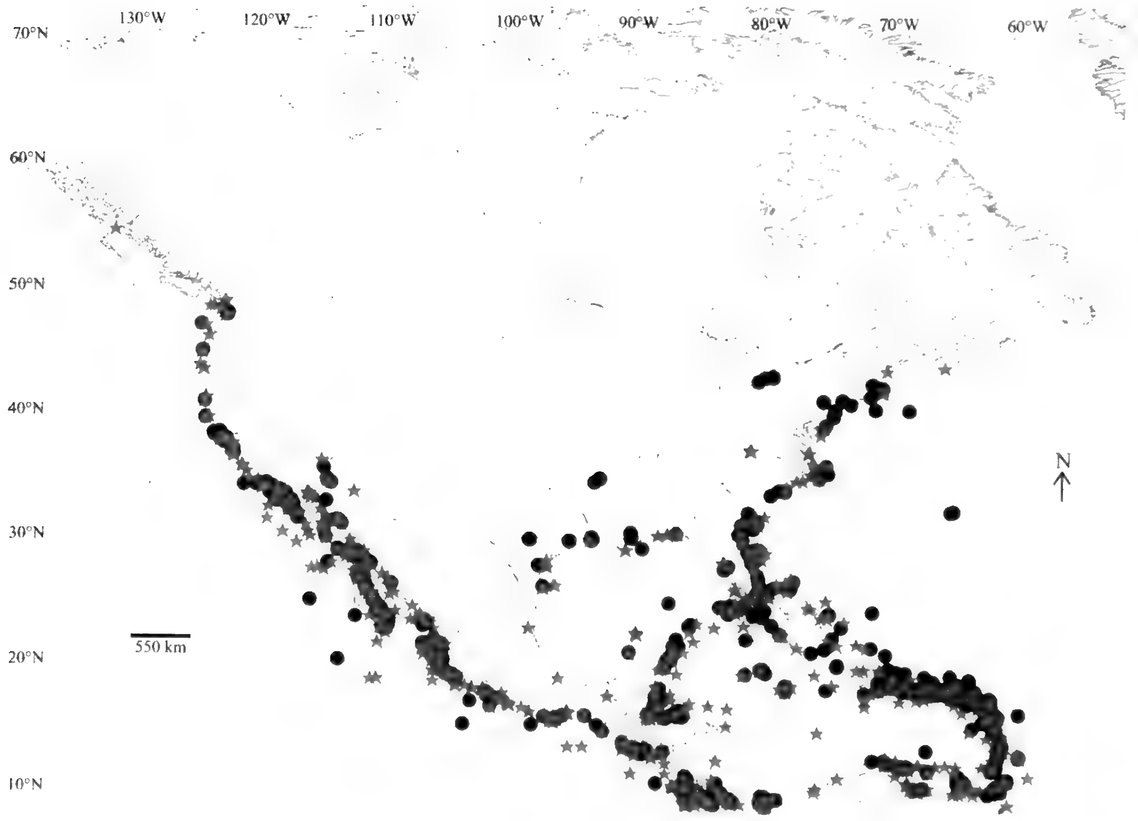

FIGURE 1. Distribution of Brown Booby (*Sula leucogaster*) based on eBird records compiled by Sullivan *et al.* (2009) and records noted by Morgan *et al.* (2009). Dots indicate records from 2012 and 2013; asterisks indicate older records.

Methods

DNA extraction

DNA was isolated from two separate fecal samples (obtained from the same location). The first sample was collected with a standard cotton swab. The feces-saturated cotton end was separated from the swab shaft and placed into a sterile 2.0-µL microfuge tube. The second sample, approximately 1 mg of dry feces, was transferred to a separate sterile 2.0-µL microfuge tube. DNA was extracted from each sample using the QIAamp DNA Stool Mini Kit (Qiagen, Hilden, Germany) following the manufacturer's "Isolation of DNA from Stool for Human DNA Analysis" protocol.

Polymerase chain reaction

Primers SlMCR-L160A and SdMCR-H750 (Steeves *et al.* 2005) were used to amplify the control region (CR2) in Brown Boobies. There are two paralogous copies of the control region and these primers specifically target the CR2 copy (Morris-Pocock, Taylot *et al.* 2010). Amplification was carried out in 25 µL reactions containing 14.7 µL distilled H_2O, 2.5 µL 10× ExTaq PCR buffer (containing 20 mM $MgCl_2$), 0.65 µL 25 mM $MgCl_2$, 1 µL of each 10 µM primers, 2 µL 10 mM dNTPs (Deoxyribonucleotide triphosphates), 0.15 µL ExTaq-HS (Hot Start) DNA polymerase (Takara Bio USA, Madison, Wisconsin, USA), and 3 µL total DNA template. Amplification cycles were performed on an Eppendorf ep Gradient S Mastercycler (Eppendorf AG, Hamburg, Germany).

DNA sequencing and editing

Amplified products were visualized on 1% agarose electrophoresis gels and purified using precast E-Gel CloneWell 0.8% SYBR Safe agarose gels (Invitrogen, Carlsbad, California, USA) following the protocol described by (Gibson *et al.* 2010). Sequencing reactions were performed in a total reaction volume of 10 µL, containing 2 µL double-distilled H_2O, 1.5 µL 5× sequencing buffer, 0.5 µL 10 µM primer, 1 µL BigDye Terminator (PE Applied Biosystems, Austin, Texas, USA), and 5 µL purified PCR product. Sequencing was performed at the Agriculture and Agri-Food Canada Eastern Cereal and Oilseed Research Centre Core Sequencing Facility, Ottawa, Ontario, Canada. Purification of sequencing reactions was performed using the Applied Biosystems (ABI) ethanol/ethylenediaminetetraacetic acid/sodium acetate precipitation protocol and reactions were analyzed on an ABI 3130xl Genetic Analyzer (PE Applied Biosystems, Foster City, California, USA).

Raw sequence chromatograms were edited and contiguous consensus sequences (contigs) were generated using Sequencher 5.0 (Gene Codes Corp., Ann Arbor, Michigan, USA). Sequences from the two samples were identical. The CR2 contig obtained was published in GenBank under number KM491177.

All 119 published control region sequences for Brown Booby were downloaded from GenBank and aligned with our contig using automated alignment programs within Geneious v5.6.5 (Biomatters Ltd., Auckland, New Zealand). Muscle, Geneious and Clustal algorithms all produced the same alignment. This was checked for obvious errors using Mesquite version 2.75 (open-source software, Mesquite Project Team, 2010, http://mesquiteproject.org). Samples were from 12 widely separated populations (broadly including the Eastern Pacific, Eastern Atlantic, Caribbean, South Pacific, and the Gulf of California) and included all four recognized subspecies (Steeves *et al.* 2005; Morris-Pocock, Steeves *et al.* 2010).

Analyses

PAUP (Phylogenetic Analysis Using Parsimony, v. 3.1, David L. Swofford, Illinois Natural History Survey, Champaign, Illinois) was used to produce a neighbour-joining tree (Figure 3, Appendix 1) and to calculate pairwise distances.

Parsimony analysis was conducted using TNT version 1.1 (Goloboff *et al.* 2008). Parsimony searches with tree bisection–reconnection branch swapping and a random stepwise addition of taxa was repeated 1000 times, followed by ratcheting, tree-fusing, sectorial searches, and tree-drifting with default settings.

Results and Discussion

The control region sequence obtained from the Lake Erie fecal samples conclusively clusters with the nominate Caribbean population of Brown Booby, *Sula leucogaster leucogaster* (Figure 3). Note that parsimony analysis found the same groups as those shown in Figure 3. The only difference is that the backbone of the tree (i.e., relationships between clades) collapses under strict consensus.

The sequence obtained was nearly identical (0.2% pairwise variation) to sequences from birds nesting on Isla Monito (18.083°N, 67.883°W) (Morris-Pocock, Steeves *et al.* 2010). Intraspecific pairwise distances within *S. l. leucogaster* vary from 0.2% to 7.8% (average 3.9%, $n = 33$). This is relatively consistent with data from other subspecies: *S. l. brewsteri*, 0.0–3.7%, average 1.7%, $n = 36$; *S. l. etesiaca*, 0.2–2.4%, average 1.3%, $n = 8$; *S. l. plotus*, 0.2–9.2%, average 5.4%, $n = 41$). Pairwise distance within subspecies averages 3.8%, and between subspecies it averages 7.1%.

We, thus, support the contention of Pawlicki (2014) that the Brown Booby found in the Great Lakes originated from the Atlantic population and refute the hypothesis that it was part of the extensive pattern of Pacific Booby vagrancy witnessed in 2013.

DNA identification from feces is still relatively novel. It has been used mostly for mammal identification, particularly in conservation-related projects (e.g., Reed *et al.* 1997; Davison *et al.* 2002; Dalén *et al.* 2004; Gompper *et al.* 2006; Napolitano *et al.* 2008; Michalski *et al.* 2011; Chaves *et al.* 2012). Only a few papers have reported using this technique for birds. For example, Cheung *et al.* (2009) surveyed avian influenza

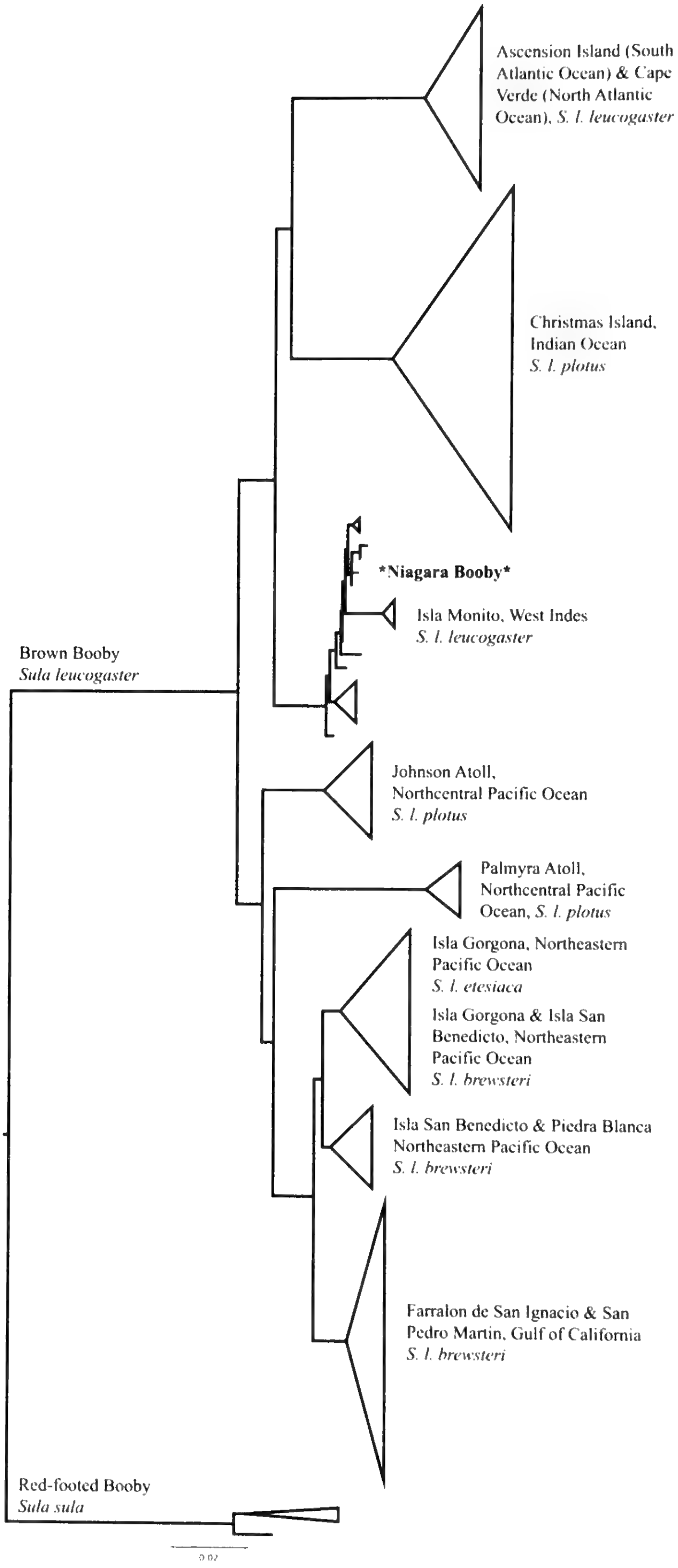

FIGURE 3. Neighbour-joining tree based on Brown Booby (*Sula leucogaster*) control region (CR2) sequences. Red-footed Booby (*Sula sula*) was used as the outgroup and to root the tree.

virus from feces and identified the bird species based on sequences of cytochrome oxidase subunit I (COI) from the same fecal matter. Joo and Park (2012) identified bird species and their prey using COI obtained from feces, and Marrero *et al.* (2008) distinguished between two threatened pigeon species by sequencing the control region from fecal samples.

We could only identify one previous study that used DNA retrieved from a fecal sample to identify a vagrant bird (Lindsay and Haas 2013). To the best of our knowledge, this paper documents the first time that DNA identification based on fecal material has been used to identify a vagrant bird in Canada. This approach has significant implications for future vagrants when morphologic identification or place of origin is unclear and a non-invasive approach is desired. For example, a vagrant *Elaenia* flycatcher turned up in Chicago in 2012, but has never been identified to species despite excellent photographic documentation (Brinkley 2012); a fecal sample might have supplied conclusive evidence for its identification. We encourage naturalists to carry a sterile cotton swab and baggie for future emergencies like this!

Acknowledgements

Support for sequencing was provided by an Agriculture and Agri-Food Canada taxonomic research grant to J. H. S. We thank Jamie Morris-Pocock for providing guidance and relevant literature at the project's inception. J. P. discovered the bird and contributed comments to the manuscript; M. J. collected the fecal sample and contributed comments to the manuscript; S. K. did the research on fecal DNA extraction, conducted the molecular work, wrote the methods section, and contributed comments to the manuscript; K. C. R. K. contributed to the analysis and commented on the manuscript; J. H. S. initiated the project, conducted the analysis, and wrote the manuscript.

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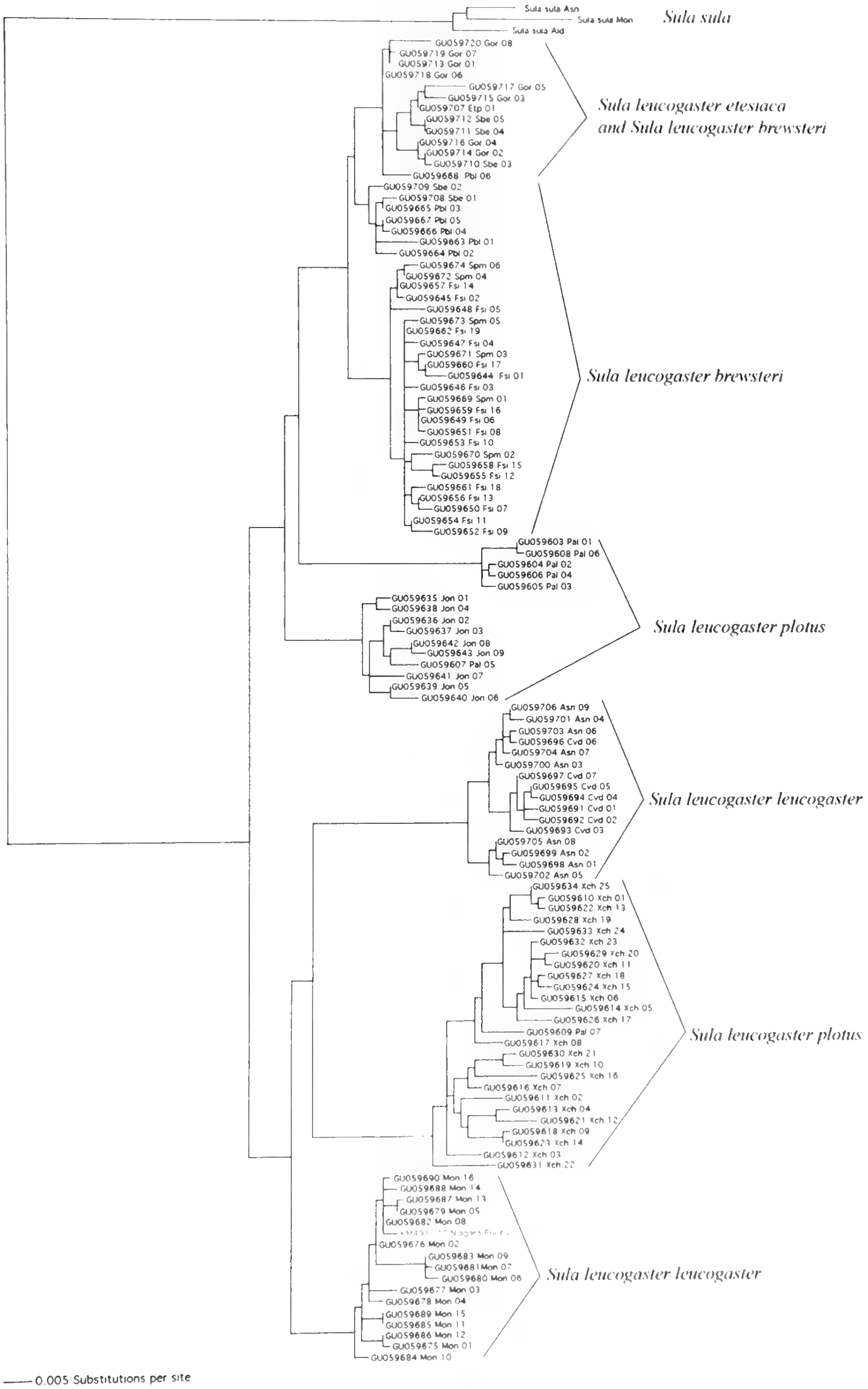
Received 13 April 2014
Accepted 9 September 2014

APPENDIX 1. Neighbour-joining tree of *Sula leucogaster* isolates, *Sula sula* used to root tree. Numbers given on branches are GenBank numbers, followed by site abbreviations and isolate numbers. Abbreviations follow Morris-Pocock *et al.* 2010 but are repeated here for clarity. ***Sula leucogaster brewsteri*** **(Northeast tropical Pacific)**: Etp – Eastern Tropical Pacific (Clipperton and Piedra Blanca), Fsi – Farralon de San Ignacio, Pbl – Piedra Blanca, Sbe – Isla San Benedicto, Spm – San Pedro Mártin, ***Sula leucogaster etesiaca*** **(Central Eastern Pacific):** Gor – Isla Gorgona, ***Sula leucogaster leucogaster*** **(Caribbean and tropical Atlantic):** Mon – Isla Monito, Asn – Ascension, Cvd – Cape Verde, ***Sula leucogaster plotus*** **(Red Sea and West Indian Ocean to Central Pacific)**: Jon – Johnston Atoll, Pal – Palmyra Atoll, Xch – Christmas Island, ***Sula sula***: Ald – Aldabra Atoll (Indian Ocean), Asn (Ascension, Eastern Atlantic), Mon (Isla Monito, Caribbean).



Notes

Egg Laying in Inappropriate Nests by the Brown-headed Cowbird (*Molothrus ater*): Acts of Parasitism or Emergency Egg Dumping?

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Sealy, Spencer G. 2015. Egg laying in inappropriate nests by the Brown-headed Cowbird (*Molothrus ater*): acts of parasitism or emergency egg dumping? Canadian Field-Naturalist 129(1): 60–69.

The generalist, brood-parasitic Brown-headed Cowbird (*Molothrus ater*) has been found to parasitize the nests of about 220 species, mostly passerine birds. Among the thousands of documented cases of parasitism are rare records of egg laying in nests in which the cowbird stands no chance of success, because its diet or developmental strategy are incompatible with those of the "host" species. Forty-four nests of 16 such inappropriate host species are reviewed: 23 nests of nine precocial species (water birds and shorebirds) plus 21 nests of seven altricial species (a raptor, doves, cuckoos, a hummingbird, and a woodpecker). Two hypotheses explain inappropriate egg laying. In the "normal laying" hypothesis, Brown-headed Cowbirds may lay dozens of eggs in nests they encounter, including the occasional inappropriate nest. In the "emergency laying" hypothesis, females, on discovering that a selected nest has failed, must lay or "dump" her eggs elsewhere, in nests of inappropriate hosts or already-parasitized nests of regular hosts. Support for either hypothesis will require electronic surveillance of movements of nest-searching and laying Brown-headed Cowbirds to generate fine-scale spatial data that confirm whether parasitism on inappropriate nests occurs at the usual laying time for pre-selected nests (around sunrise) or later in the day if the chosen nest has failed and emergency laying is required.

Key Words: brood parasitism; Brown-headed Cowbird; egg dumping; emergency egg laying; host incompatibility; host selection; laying time; multiple parasitism; *Molothrus ater*

Introduction

Obligate avian brood parasitism is a reproductive strategy in which a female lays all of her eggs in another species' nest and relies on the "host" to rear her young. Hosts that accept the parasitic young usually experience reduced reproductive success, which has resulted in the evolution of a suite of adaptations by hosts to counter these costs (Payne 1977; Rothstein 1990; Ortega 1998; Davies 2000). The success of parasitism among potential host species is variable and, therefore, we may ask: what constitutes a good host? When any bird lays an egg in another bird's nest, the probability of success is increased if the host species is able to raise the parasite's offspring to independence. Friedmann (1929, 1963) proposed four requirements with respect to the suitability of hosts of parasitic cowbirds (*Molothrus* spp.): (1) they exhibit an altricial post-hatching pattern of development, (2) they lay eggs not much larger than the cowbird's, (3) they exhibit the "normal method" of feeding nestlings, i.e., adults placing food into the nestlings' gaping bills, and (4) they feed young a "typical passerine" (arthropod) diet that will also sustain the cowbird's development (also see Ortega 1998; Peer and Bollinger 1998). Underlying these conditions is the basic one that the host accepts foreign eggs (Rothstein 1975).

Eggs of the obligate brood-parasitic Brown-headed Cowbird (*Molothrus ater*) have been found in nests of more than 220 species of birds, of which more than 140 species of passerine birds have been documented as fledging the parasite's young (Lowther 2010). The Brown-headed Cowbird, therefore, has been designated a generalist parasite because of its use of so many hosts, in contrast to many species of parasitic cuckoos in which females parasitize only a single host species (Davies 2000). Among the species whose clutches have been recorded receiving one or more Brown-headed Cowbird eggs are ones in which the young parasite, even if hatched, stands no chance of survival because the patterns of development of host and cowbird are completely incompatible. This is termed "inappropriate" laying, although it has also been called "egg-dumping" and "freak" or "accidental" laying by other authors (e.g., Friedmann 1966; Friedmann *et al.* 1977). The host species may be precocial (e.g., ducks and shorebirds) and, because the young leave the nest within a few hours of hatching, the cowbird is left behind. Other inappropriate hosts, however, may be altricial (e.g., doves and cuckoos); although the young develop in the nest, the cowbird's diet requirements are not met. Speculation on the reasons for inappropriate laying has focused on indiscriminate laying by Brown-headed Cowbirds or females committed to laying their eggs on a given morning forced at the last minute to lay elsewhere, after discovering their previously selected nest has been destroyed.

Objectives

The first objective of this review was to compile the anecdotal records of inappropriate laying by the Brown-headed Cowbird that are scattered throughout the literature, although most have been included in host catalogues and supplements compiled by Friedmann (1931, 1963, 1966, 1971), Friedmann *et al.* (1977), and Friedmann and Kiff (1985) and, more recently, listed in Ortega (1998) and Lowther (2010). I corresponded with curators of egg collections and, if possible, original observers to augment details of records and clarify information on the provenance of clutches and success of host and cowbird. This met with variable success, but I summarized the information available for each record regardless of completeness to bring the records up to date.

The second objective was to examine the act of inappropriate laying in the context of results of recent studies of nest-searching behaviour and time of day of laying by Brown-headed Cowbirds and hosts and to suggest studies using techniques of electronic surveillance of nest-searching and laying females to remove the anecdotal records from the realm of speculation.

In the "normal laying" hypothesis, Brown-headed Cowbirds lay dozens of eggs in random nests as encountered, including the occasional inappropriate nest or already-parasitized nest of a regular host. In the "emergency laying" hypothesis, females that discover that a previously selected nest has been destroyed, unable to retain their hard-shelled eggs in the oviduct for more than a few hours, need another place to lay. Laying in inappropriate nests would be expected to occur around sunrise, at the cowbird's normal laying time (Scott 1991; McMaster *et al.* 2004), if nests are preselected, or later in the day if laying is an emergency.

Records of Inappropriate Laying

Inappropriate laying is a rare event. Forty-four nests of 16 inappropriate "host" species have been recorded: 23 nests of nine precocial species, i.e., water birds and shorebirds, and 21 of seven altricial species, i.e., a raptor, doves, cuckoos, a hummingbird, and a woodpecker (Appendix I). All nests received one cowbird egg, except for a Blue-winged Teal (*Anas discors*) nest that received two cowbird eggs plus a third cowbird egg discovered on the ground nearby and two Wilson's Phalarope (*Steganopus tricolor*) nests that each received two cowbird eggs. Sixteen (69.5%) of the 23 cases of inappropriate parasitism on precocial species involved four species of shorebird, but, among these, eight (50%) were of parasitism on the Spotted Sandpiper (*Actitis macularius*). Frequency of parasitism on the 21 altricial species involved eight records (38.1%) of doves and 10 records (47.6%) of cuckoos.

The rarity of cowbird parasitism on two inappropriate host species listed in Appendix I (Mourning Dove [*Zenaida macroura*] and Black-billed Cuckoo [*Coccyzus erythropthalmus*]) was confirmed by co-workers and me; we recorded no parasitism on over 400 nests of the former species and over 60 nests of the latter, examined over more than 35 years (1974–2010) of monitoring a Brown-headed Cowbird host community at Delta Marsh, Manitoba. Mourning Doves eject some cowbird eggs from their nests (Peer and Bollinger 1998), but we likely would have recorded some parasitism on this species, even if it had occurred infrequently.

Of the 23 parasitized nests of precocial species, (1) six failed (three depredated, two flooded, and one deserted before cowbird eggs were laid); (2) cowbird egg(s) disappeared from three (one nest later depredated); (3) a cowbird egg was collected from one nest, but the host clutch remained active; (4) host eggs but not cowbird eggs hatched at three nests; and (5) fates were undetermined at 10 nests. Of the 22 parasitized nests of altricial species, (1) two failed (one depredated and one deserted); (2) a cowbird egg disappeared from one nest that was later depredated; (3) parasitized clutches were collected from five nests; (4) a cowbird egg hatched, but the nestling disappeared from one nest; (5) unsubstantiated record of cowbird fledging from one nest; and (6) fates were undetermined at 11 nests.

Discussion

Parasitism on nests in which a young Brown-headed Cowbird stands no chance of success is extremely rare, in light of the thousands of reports of parasitism on nests of passerine species that traditionally serve as hosts (lists compiled by Herbert Friedmann and colleagues [also references in Appendix I]; also Ortega 1998; Lowther 2010). This parasitism is probably inconsequential to the reproductive success of parasite and host and, therefore, of little evolutionary importance. Nests that failed apparently did so unrelated to parasitism or the clutches were collected by oologists; nests that remained active generally were not inspected frequently enough to determine the outcome (Appendix I). The cowbird's success was limited in the first place because of its 10- to 11-day incubation period (Briskie and Sealy 1990); thus, if hatching had occurred, the cowbird would have hatched before host young and perished from lack of parental care.

It is most interesting that this laying occurs at all, in light of the time of day of nest searching and laying by Brown-headed Cowbirds. Were these nests previously selected for parasitism or were they used as receptacles for eggs laid in an emergency after the cowbird discovered its chosen nest had failed? Studies of ovarian development of cowbirds, based on dissections of gravid females collected over the breeding season (Payne 1976; Scott and Ankney 1980, 1983) or keeping track of eggs laid in aviaries (e.g., King 1979; Holford and Roby 1993) have shown that some females are capable of laying up to several dozen eggs during the breeding season. This has led some authors to suggest that females parasitize nests as they encounter them, regardless of the potential for success, i.e., a "shotgun" approach (e.g., Preston 1948; Rothstein 1976), in the likelihood that a young cowbird will be reared. Recent studies involving molecular genetic techniques, however, have revealed that cowbirds lay fewer, more valuable eggs during the breeding season, which suggests selectivity among nests parasitized (reviewed *in* Sealy *et al.* 2002).

The following scenario may be envisioned, leading up to a Brown-headed Cowbird laying in an inappropriate nest. Laying occurs during a remarkably short and consistent 20-minute "window" around sunrise (Scott 1991; McMaster *et al.* 2004; Ellison and Sealy 2007), before potential hosts have laid (Neudorf and Sealy 1994). Females then generally search for and apparently select the next nest for parasitism, although nothing is known about whether females "line up" nests for parasitism. By late morning, females have generally left the host nesting area and travelled to areas to forage, eventually flying to a roost site in the evening (e.g., Rothstein *et al.* 1984; Curson *et al.* 2000). Before sunrise the next morning, females fly directly to the selected nest, approach it "stealthily," often in the dark (Scott 1991; Sealy *et al.* 2000; Sealy and McMaster 2004), and parasitize it within a few seconds (Sealy *et al.* 1995). If the selected nest has been depredated, has failed because of inclement weather, or the cowbird's attempt to parasitize it is thwarted by aggressive adults (Neudorf and Sealy 1994; also see Ellison and Sealy 2007), the female is forced to lay its egg elsewhere, which possibly accounts for records of laying 2–3 h after sunrise (e.g., Friedmann 1929; Kinser 1973).

Knowledge of the time of day cowbirds parasitized a sandpiper's, duck's, or dove's nest should reveal whether the nest has been selected originally for parasitism or parasitized in an emergency. If selected previously, the nest would be expected to have been parasitized around sunrise, the cowbird's usual laying time; if the cowbird had been forced to use the nest as an alternative receptacle, parasitism would probably have occurred later in the day. If no alternative nest is available, the cowbird may be forced to lay the egg on the ground, possibly eating it and gaining nutrients (Scott *et al.* 1992). Rather than discard the egg in an emergency, however, cowbirds may benefit by laying in already-parasitized nests.

Friedmann (1929) noted in passing that, in an emergency, a cowbird may lay in a nest of one of its regular hosts, even if it or another female has already parasitized it. In this case, young may be produced, which would account for the rarity of finding cowbird eggs laid on the ground. Multiple parasitism (more than one cowbird egg in a clutch) occurs frequently in many host populations (e.g., Ortega 1998; Trine 2000), including three species of hosts at Delta Marsh (Sealy 1992; Woolfenden *et al.* 2004). Using techniques of molecular genetics, two different groups of female Brown-headed Cowbirds were identified laying in already-parasitized nests: different females parasitizing the same nest and the same females parasitizing a nest again (McLaren *et al.* 2003; also see Ellison *et al.* 2006). Females that re-parasitize a nest may be laying in an emergency, possibly later in the morning, but without information on the time of day of laying by all cowbirds at multiply parasitized nests, repeated parasitism has been assumed to be normal laying. Data on timing of multiple parasitism in southern Texas (Ellison and Sealy 2007), obtained through watches at host nests of Brown-headed Cowbirds and Bronzed Cowbirds (*M. aeneus*), revealed that despite frequent multiple parasitism, usually by several females on the same nest and morning (Ellison *et al.* 2006), cowbirds tended to visit nests alone. More than one Brown-headed Cowbird arrived at the same nest only twice and, in each case, both cowbirds parasitized the nests. It was not known, however, whether both individuals had selected these nests for parasitism on those particular mornings.

Future Directions

Explanations for parasitism by Brown-headed Cowbirds on inappropriate hosts and elucidation of details of nest-searching behaviour in general will remain mostly speculative until researchers employ recent advances in electronic surveillance, such as passive integrated transponder technology, with passive readers and antennae (Smyth and Nebel 2013) or radio-telemetry in the same way (Wyllie 1981; Honza *et al.* 2002) to track the female cowbird's every movement during the breeding season. This technology may enable collection of the fine-scale spatial data necessary to reveal which nests are selected for parasitism and parasitized. Perch sites and the time spent on them by females could be measured in relation to the nest that is to be parasitized, linking perch site and host nest and, thus, confirming parasitism on selected nests at dawn (Scott 1991; McMaster *et al.* 2004). Nests inspected later by the researcher would confirm parasitism, because the tracking system would only reveal that the nest had been visited by a particular cowbird at a particular time, not that the cowbird had parasitized it. (Video cameras positioned above [open-cup] nests may confirm that parasitism occurred [Sealy *et al.* 2000], whereas nests would be inspected daily to monitor contents leading up to parasitism.) Information processed by nest-searching female Brown-headed Cowbirds and other brood parasites likely involves interactions among body condition and fecundity, availability of suitable hosts, responses to features of the landscape, and spatial memory; gathering such information requires continuing studies in the laboratory and detailed monitoring of movements of free-ranging individuals (e.g., Rothstein *et al.* 1987; Gates and Evans 1998; White *et al.* 2009; Guigueno *et al.* 2014).

Acknowledgements

Many people verified the accuracy of records or provided additional details gleaned from files associated with egg collections or from other sources: M. Brodsky (Special Collections, Virginia Tech University, Blacksburg, Virginia, USA), R. W. Campbell (Biodiversity Centre for Wildlife Studies, Victoria, British Columbia, Canada), R. Corado (Western Foundation of Vertebrate

Zoology, Caramillo, California, USA), B. D. Dugger and R. T. Mason (Oregon State University, Corvallis, Oregon, USA), T. C. Erdman (Richter Museum of Natural History, University of Wisconsin-Green Bay, Wisconsin, USA), J. Hudon (Royal Alberta Museum, Edmonton, Alberta, Canada), R. L. McKernan (San Bernardino County Museum, Redlands, California, USA), R. Mooi (The Manitoba Museum, Winnipeg, Manitoba, Canada), L. W. Oring (University of Nevada, Reno, Nevada, USA), M. Peck (Royal Ontario Museum, Toronto, Ontario, Canada), J. L. Rasmussen (University of Manitoba, Winnipeg, Manitoba, Canada), G. W. Shugart (Slater Museun of Natural History, Tacoma, Washington, USA), J. L. Woods (Delaware Museum of Natural History, Wilmington, Delaware, USA), and R. M. Zink (Bell Museum of Natural History, University of Minnesota, St. Paul, Minnesota, USA). The associate editor and two reviewers provided helpful comments on the manuscript. Publication costs for this article were supported by the Thomas H. Manning Fund of The Ottawa Field-Naturalists' Club.

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Received 8 April 2014
Accepted 13 June 2014

APPENDIX 1. Records of egg laying by Brown-headed Cowbirds (*Molothrus ater*) in the nests of inappropriate species of birds.

Host species	Notes[1]
Precocial[2]	
Blue-winged Teal (*Anas discors*)	1. Manitoba, 8 June 1956: 3 he, 2 ce. The Blue-winged Teal flushed from an empty nest bowl on 2 June; 6 days later, three teal eggs had been depredated, apparently by a Striped Skunk (*Mephitis mephitis*), but two intact cowbird eggs were present in the nest bowl and a third cowbird egg was on the ground "about 30 yards from the destroyed nest," on 11 June (Hamilton 1957: 279). It was not known whether the teal was still attending the nest when the first cowbird egg was laid (Friedmann 1963: 45).
	2. Manitoba, 30 May 1976: 4 he, 1 ce. Nest contained seven Blue-winged Teal eggs and no cowbird egg on 1 June (Gardner 1981: 151).
Lesser Scaup (*Aythya affinis*)	1. Manitoba, 16 June 1999: 6 he, 1 ce. By 22 June, 10 Lesser Scaup eggs were being incubated, but the Brown-headed Cowbird egg was missing; the nest was depredated by 26 June (Koons 2000: 554). The disappearance of the cowbird egg was interpreted as an act of ejection (Koons 2000). Laying of successive eggs, including the cowbird egg, followed by its disappearance, conform to the criteria for ejection by a host (Rothstein 1975), i.e., the parasite's egg disappeared and, in this case, the Lesser Scaup continued to attend the clutch, laying four additional eggs after the cowbird egg disappeared.
Virginia Rail (*Rallus limicola*)	1. Ontario, 7 June 1971: 8 he, 1 ce. The Virginia Rail was observed on, or flushed, from the nest five times between 6 and 11 June, with eight rail eggs recorded in total (cowbird egg was collected); two young rails were observed with adults on 11 July (ONRS, Royal Ontario Museum; confirmed by M. Peck, email, 31 October 2011; also see Friedmann *et al.* 1977: 10; Peck and James 1983: 153).
Killdeer (*Charadrius vociferus*)	1. Manitoba, 1963: 4 he, 1 ce. Reported by Mossop (1963: 24) but details are incomplete: "[Brown-headed] cowbird egg resting snugly with the usual foursome of Killdeer's very much larger eggs" (also see Hatch 1971: 18; Friedmann *et al.* 1977: 10).
Spotted Sandpiper (*Actitis macularius*)	1. Alberta, 5 June 1960:[3,4] Reported with no details by Friedmann *et al.* (1977: 10).
	2. Alberta, 1964[3], 1 ce. Reported by R. W. Turner as "another cowbird egg was found in a Spotted Sandpiper nest" (Lister 1964: 518; also see Friedmann 1966: 2; Sadler and Myres 1976: 233).
	3. Ontario, 5 June 1965: 4 he, 1 ce. No other details (ONRS; confirmed by M. Peck, email, 31 October 2011; also see Friedmann *et al.* 1977: 10; Peck and James 1983: 179).
	4. Utah, 2 June 1968:[3], 1 ce. M. F. Baker discovered a Spotted Sandpiper nest with one cowbird egg, but no other details are available (Friedmann 1971: 241).
	5. British Columbia, June 1964: 3 he, 1 ce. Record extracted from field notes of the late J. G. Sarles by R. W. Campbell, communicated to McNicholl (2009: 168).
	6. Manitoba, 26 June 1970: 4 he, 1 ce. Brown-headed Cowbird egg surrounded by "the usual four" Spotted Sandpiper eggs, each pointing inward, "suggesting that the egg had been accepted"; the nest had been destroyed by 8 July before fates of the eggs could be determined (Hatch 1971: 17-18; also see Friedmann *et al.* 1977: 10).
	7. Minnesota[3,4] . Oring (1997: 18; email, 1 November 2011) reported "parasitism by… Brown-headed Cowbird observed twice in 19 [years] in [north-]central Minnesota, but hatching [of cowbirds] unsuccessful."
	8. British Columbia, 6 June 1984: 3 he, 1 ce. Spotted Sandpiper flushed from nest containing four warm eggs, one of which was a Brown-headed Cowbird egg (Siddle 2008: 215; also see Campbell *et al.* 1992: 152).

APPENDIX I. *(continued)*

Host species	Notes[1]
Precocial[2]	
Upland Sandpiper (*Bartramia longicauda*)	1. Minnesota: 4 he, 1 ce. "[Brown-headed] Cowbird's egg was almost buried in the bottom of the nest" (Friedmann 1931: 60); the parasitized clutch was originally in the J. Hooper Bowles egg collection, but it was not located. 2. North Dakota, 18 June 1971: 3 he, 1 ce. Upland Sandpiper flushed from nest (18 and 28 June); shell fragments and membranes of hatched sandpiper eggs and a punctured Brown-headed Cowbird egg were present on 12 July (Higgins 1971: 79; also see Stewart 1975: 235). 3. North Dakota, 1 June: 3 he, 1 ce. Adult flushed from nest on 1 and 3 June, but the clutch of three Upland Sandpiper eggs was destroyed by 5 June (Higgins and Kirsch 1975: 98). 4. Manitoba, 6 July 1991: 3 he, 1 hy, 1 ce. Upland Sandpiper was flushed from the nest, but nest could not be located on 8 July to confirm hatching of the other sandpiper eggs or the Brown-headed Cowbird egg (Davis *et al.* 1999).
Wilson's Phalarope (*Steganopus tricolor*)	1. Utah, 6 June 1938: 4 he, 2 ce. This and the following Wilson's Phalarope nest were about 7.5 m apart on a small artificial island in a marsh; the four phalarope eggs in one nest had hatched by 21 June, but the two Brown-headed Cowbird eggs remained and were later flooded; one cowbird egg "was evidently infertile, but the others [including two from the nest below] were advanced in development" (Williams and Trowbridge 1939: 77; also see Friedmann 1943: 353). 2. Utah, 6 June 1938: 4 he, 2 ce. On 28 June, three phalarope eggs had hatched, but the fourth egg, which was pipped, and both cowbird eggs had been destroyed by flooding (Williams and Trowbridge 1939: 77; also see Friedmann 1943: 353). 3. Manitoba, 15 June 1970: 4 he, 1 ce. The cowbird egg rested along the edge of the phalarope eggs, but the fate of the eggs was not determined (Hatch 1971: 17; also see Friedmann *et al.* 1977: 10).
California Gull (*Larus californicus*)	1. North Dakota, June 1899:[3,4]. A California Gull nest contained "several eggs of its own and one of the [Brown-headed] cowbird" Friedmann (1963: 46).
Common Tern (*Sterna hirundo*)	1. Saskatchewan, 7 July 1979: 2 he, 1 ce. This was the only record of a Brown-headed Cowbird egg in a tern or any other nest in 18 years of banding at Redberry Lake (Houston and Brown 1982: 57; also see Freidmann and Kiff 1985: 244).
Altricial[2]	
Ferruginous Hawk (*Buteo regalis*)	1. North Dakota, 3 May 1894: 4 he, 1 ce. A. Eastgate reported a nest with a Brown-headed Cowbird egg that Friedmann (1929: 206) described as "a purely accidental host." In fact, the cowbird egg may not have been laid there in the first place. Houston (1975) recorded eggs of three prey species in Great Horned Owl (*Bubo virginianus*) nests, possibly discarded when prey was being apportioned for the young. However, this hawk's nest already contained eggs when the cowbird's egg appeared, rendering this scenario unlikely. The cowbird may have targeted a House Sparrow's (*Passer domesticus*) nest built on the side of the hawk's nest, as this sparrow is occasionally parasitized (Friedmann *et al.* 1977: 32).
Mourning Dove (*Zenaida macroura*)	1. Iowa:[3,4]. A report by E. H. King is lacking details, but noted that "the [Mourning] Dove is the largest bird [King] had known to be chosen as the Cowbird's foster-parent" (Coues 1884; also see Friedmann 1929: 206). 2. Pennsylvania, 25 May 1899: 2 he, 1 ce. A dubious record reported by Kellogg (1900: 121) of "a [Brown-headed] Cowbird flutter[ing] off an old Grackle's nest, [which] on examination... the nest [was found] to contain a Cowbird's egg." Three days later a clutch of two Mourning

Appendix I. *(continued)*

Host species	Notes[1]
Altricial[2]	
Mourning Dove (*Zenaida macroura*)	Dove eggs had been laid in the nest, but three weeks later the nest contained "a Cowbird ready to fly." The record is accompanied by a photograph showing the young cowbird and two dove eggs, but Friedmann (1963: 47) found this record unconvincing because adult doves were not observed at the nest; the grackles that built the nest may have taken it over and reared the cowbird; and the Mourning Dove's method of feeding young is incompatible with feeding of a young cowbird. 3. Ohio:[3,4]. Without details, one dove's nest was reported as parasitized among 41 host species recorded by Hicks (1934; also see Friedmann 1963: 46). 4. Manitoba, 15 June 1965: 1 he, 1 ce. One dove egg was present on 4 June; cowbird egg laid 15 June but gone by 17 June; two dove eggs later disappeared (McNicholl 1968: 22). 5. Saskatchewan, 4 June 1967: 1 he, 1 ce. Nest contained one dove egg on 20 May 1967; by 4 June the nest was deserted but contained one egg each of dove and cowbird; underneath the nest was a broken dove egg (Buckle 1969: 170; also see Hooper 1992: 84).
Common Ground-Dove (*Columbina passerina*)	1. Texas, 23 May 1925: 2 he, 1 ce. Friedmann found this nest, reporting that it was the only one parasitized among 10 Common Ground-Dove nests examined. Another parasitized nest discovered "from the same district years earlier" was reported without details by R. D. Camp to Friedmann (1929: 206; also see Friedmann 1963: 48). 2. Texas, 24 May 1927: 2 he, 1 ce. R. D. Camp collected a parasitized clutch of the Common Ground-Dove that is now WFVZ no. 59610 (R. Corado, email, 7 April 2014; also see Friedmann 1929: 206). 3. Texas, 4 June 1927:[3,4]. Friedmann *et al.* (1977: 11) reported that this parasitized clutch was in the museum of Oregon State University, but there is no record of it in that collection (B. D. Dugger, email, 26 March 2014).
Yellow-billed Cuckoo (*Coccyzus americanus*)	1. Connecticut, 8 June 1875:[3,4]. Friedmann (1963: 48) reported this parasitized egg set, collected by F. Benners, catalogued in the (Bell) Museum of Natural History (no. 39), University of Minnesota; however, the host was recorded as the Black-billed Cuckoo and both the single Black-billed Cuckoo's egg and presumably the single cowbird's egg are missing (R. Zink, email, 16 January 2014). 2. Illinois, before 1893:[3,4], 1 ce. Record of nest with one cowbird egg observed by W. E. Loucks, without supporting evidence, "sometime prior to 1893" (Friedmann 1934: 29, 1949: 158, 1963: 48). This record formed the basis for inclusion of this species in Bendire's (1895: 594) list of host species of the Brown-headed Cowbird. 3. Pennsylvania, 30 April 1912: 4 he, 1 ce. Friedmann (1971: 242) reported this parasitized clutch, collected by A. Benners and originally housed in the Rockbridge Alum Springs Biological Laboratory, Goshen, Virginia (M. Brodsky, email, 13 January 2014). The egg set is now WFVZ no. 59747 (R. Corado, email, 7 April 2014). 4. Ohio, before 1934: 5 he, 1 ce. One of eight Yellow-billed Cuckoo nests inspected 1922–1934, but dates of observations of the nests, including the parasitized nest, were not given (Trautman 1940: 273, 393; also see Friedmann 1949: 158). 5. Kansas, 20 June 1962: 1 he, 1 ce. The nest was empty on 25 June ("Woods" 1972: 14-15; also see Friedmann *et al.* 1977: 11).
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	1. New York:[3], 1 ce. This record was obtained by F. Morris and E. A. Eames who documented it in the botanical literature; Friedmann (1943: 353) pointed it out to ornithologists. 2. Maryland, 26 May 1932: 1 he, 1 ce. Details were provided by R. E. Stewart to Friedmann (1963: 48; also see Stewart and Robbins 1958: 329).

APPENDIX I. *(continued)*

Host species	Notes[1]
Altricial[2]	
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	3. Quebec, 15 June 1938: 2 he, 1 ce. The information pertaining to this clutch was sent to Friedmann (1963: 48) by L. M. Terrill. 4. Michigan, 24 June 1969: 2 hy, 1 ce. One of 14 Black-billed Cuckoo nests inspected in 1968 and 1969 by S. I. Rothstein. At the parasitized nest, the cowbird egg was gone on 27 June, but "2 half-shells from it were found almost directly beneath the nest. The half-shells were dried out, indicating that the cowbird egg had hatched. Probably, since the usual food of cuckoos — bristly caterpillars — was unsuitable to the cowbird infant, it died shortly after hatching and its dead body was removed by the host" (Friedmann *et al.* 1977: 11). 5. Wisconsin, 13 July 1957: 2 he, 1 ce. Egg set collected by C. H. Richter and housed in Richter Natural History Collection, University of Wisconsin, Green Bay (Friedmann and Kiff 1985: 244). Sent to J. Hurley, Yakima, Washington, on 21 October 1958 (T. Erdman, email, 15 January 2014), but current whereabouts of the Hurly collection, including this egg set, is not known.
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	1. Ohio:[3]. Listed as a host of the Brown-headed Cowbird, without supporting data, by Bendire (1895: 594) and Davie (1898: 339). Friedmann (1963: 49) referred to another vague record communicated to him by L. Jones, who wrote that he had taken a cowbird's egg from a nest of [Red-headed Woodpecker] in Ohio "many years ago," but supplied no details.
Ruby-throated Hummingbird (*Archilochus colubris*)	1. Massachusetts, July 1890: 0 he, 1 ce. Report of a Ruby-throated Hummingbird's nest "completely filled" by a Brown-headed Cowbird's egg (Anonymous 1891: 109). Friedmann (1929: 206-207) initially doubted this record, believing the nest was likely that of an Eastern Wood Peewee (*Contopus virens*), but he decided later to accept this improbable record because a cowbird egg would not fill the cup of a peewee's nest (Friedmann 1963: 58).

Note: he = host egg(s), hy = host young, ce = Brown-headed Cowbird eggs, ONRS = Ontario Nest Record Scheme, WFVZ = Western Foundation of Vertebrate Zoology.

[1] Location, date, and contents of nest recorded when first inspected.

[2] Post-hatching mode of development.

[3] Number of host eggs unknown.

[4] Number of cowbird eggs unknown.

Range Extension for Pygmy Whitefish (*Prosopium coulterii*) in the Northwest Territories, Canada

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Vecsei, Paul, and Damian Panayi. 2015. Range extension for Pygmy Whitefish (*Prosopium coulterii*) in the Northwest Territories, Canada. Canadian Field-Naturalist 129(1): 70–75.

We document the first occurrence of Pygmy Whitefish (*Prosopium coulterii*) in the Northwest Territories outside of Great Bear Lake. Six specimens were captured in Bluefish Lake in September 2012. Bluefish Lake is on the Yellowknife River, approximately 25 km upstream from Great Slave Lake.

Key Words: Range extension; Pygmy Whitefish; *Prosopium coulterii*; Northwest Territories; Coregoninae; distribution; Bluefish Lake; Yellowknife Lake; Great Slave Lake

Introduction

The Pygmy Whitefish (*Prosopium coulterii*) is the smallest member of the subfamily Coregoninae. It has large scales, large eyes, a blunt snout with a subterminal mouth, and a cylindrical body. Its gill rakers are short and number between 13 and 20. Scales along the lateral line range between 54 and 70 (Eschmeyer and Bailey 1955). The Pygmy Whitefish is typical of fishes in the genus *Prosopium* in having a single internarial flap (McPhail and Lindsey 1970). Colouration is typically brownish along the dorsum with dark parr marks even in adults (Scott and Crossman 1973; Nelson and Paetz 1992; Mecklenburg *et al.* 2002). Ventral fins of both sexes become dark yellow or orange during spawning (Heard and Hartman 1965). Fecundity is lower than other coregonids, with egg production ranging from 97 to approximately 1000 (Weisel *et al.* 1973). Mean egg size in Alaska was 2.4 mm (Heard and Hartman 1965). Although the largest recorded egg size is 262 mm (McCart 1963), the maximum size rarely exceeds 140 mm (Eschmeyer and Bailey 1955; Mackay 2000*).

The Pygmy Whitefish has a wide discontinuous distribution in North America (Scott and Crossman 1973; Hallock and Mongillo 1998*; McPhail 2007* Sullivan 2011*) that includes Lake Superior (Ontario, Michigan, and Wisconsin); Yukon River drainage (northern British Columbia, Yukon, and Alaska); southwestern Alaska (Chignik, Naknek, and Wood River drainages); and the Columbia River drainage (western Montana, Washington, and British Columbia).

The Pygmy Whitefish has also been reported from Great Bear Lake, Northwest Territories, and Lake Athabaska, Saskatchewan (Nelson and Paetz 1992; Dr. Michael Sullivan, Provincial Fisheries Science Specialist, Sustainable Resource Development, Fish and Wildlife Division, Government of Alberta, personal communication, 2013) and from the Chukotski Peninsula in Russia (Chereshnev and Skopets 1992). The Pygmy Whitefish likely had a more continuous distribution during the late Pleistocene, but was isolated during the retreat of the Wisconsin glaciation (Eschmeyer and Bailey 1955).

In lakes, the Pygmy Whitefish ranges from shoreline habitat to waters as deep as 168 m (Heard and Hartman 1965; Lindsey and Franzin 1972). At northern latitudes, the species is most common in shallow water. Although the Pygmy Whitefish is typically lake dwelling, it also occurs in fast-moving montane rivers and streams that are clear or silted (McPhail and Lindsey 1970; Mayhood 1992*).

Spawning typically occurs in the late fall from November to December (Schultz 1941*; Weisel and Dillon 1954; Eschmeyer and Bailey 1955; McCart 1963; Heard and Hartman 1965; Hallock and Mongillo 1998*). Males mature at age 1 year and females at about 2 years (Wiesel *et al.* 1973). Maximum reported ages are typically 5–7 years (Eschmeyer and Bailey 1955).

Methods

We conducted a fish survey in Bluefish Lake from September 26 to October 1, 2012. Bluefish Lake is a natural widening of the Yellowknife River upstream from Prosperous Lake (Figure 1), and approximately 25 km upstream from Yellowknife Bay in Great Slave Lake.

Fish were collected using bottom-set, graded-mesh gillnets. Nets were 75 m long by 1.8 m high and composed of five, 15-m panels of 21.5-, 45.8-, 70.1-, 97.5-, and 120.4-mm stretched mesh. Nets were deployed overnight for more than 12 h at a depth of 25–33 m.

The entire catch was sorted and coregonids were processed as soon as possible after capture. A digital image of the left side of each individual was made using a Nikon D700 camera (Nikon Canada, Mississauga, Ontario, Canada). Fish were displayed on a flat pale pink surface with their fins pinned in the open position and a ruler added for scale (Figure 2). Dorsal views were also taken to illustrate spotting along the dorsal surface and flank. Each fish was individually bagged, labeled, and transferred to a freezer before processing in the laboratory.

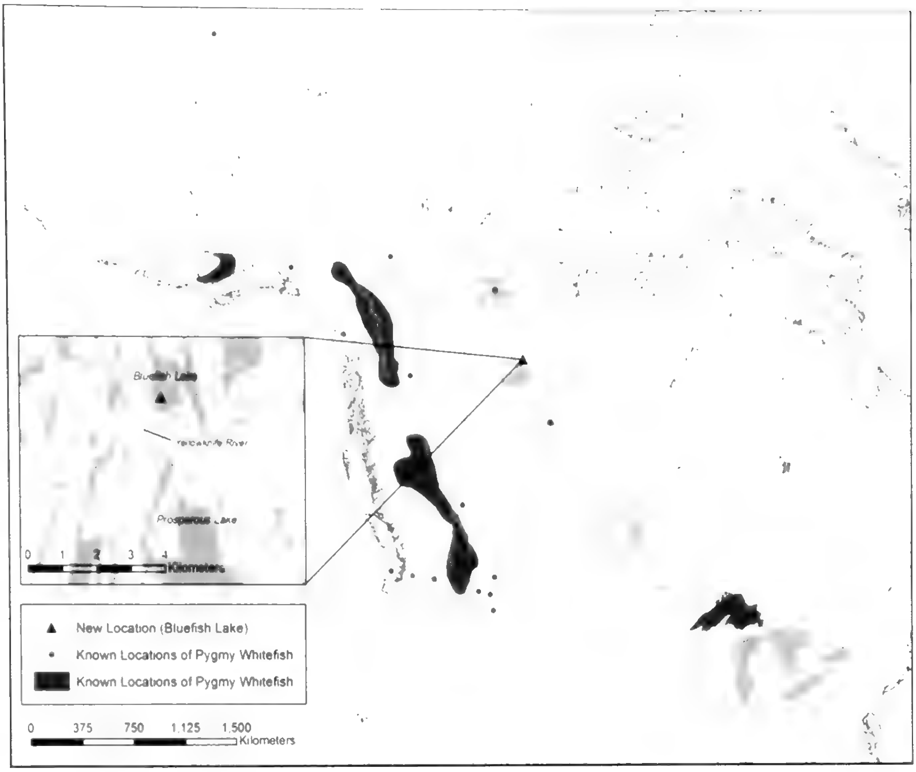

FIGURE 1. Distribution of the Pygmy Whitefish (*Prosopium coulteri*). Shaded areas and circles indicate known locations; the triangle shows the new location at Bluefish Lake, Northwest Territories.

Twenty-three linear morphometric and seven meristic characteristics were quantified following Vuorinen *et al.* (1993). All linear measurements were made point-to-point on the left side of the fish using digital calipers (± 0.01 mm). After measurements were made, the first left gill arch was extracted. Gill raker enumeration was done under a Leica ES2 dissection scope (Leica Microsystems Inc., Concord, Ontario, Canada) with reflected light at a magnification between 10× and 30×. All rakers were counted, including rudimentary rakers at the base of the arch. Scales in the lateral line were enumerated to the end of the hypural complex; where scales were missing because of damage during handling, scale pockets were counted. For fin ray enumeration, the anterior rays were excluded unless they were at least two-thirds the length of the longest ray. When

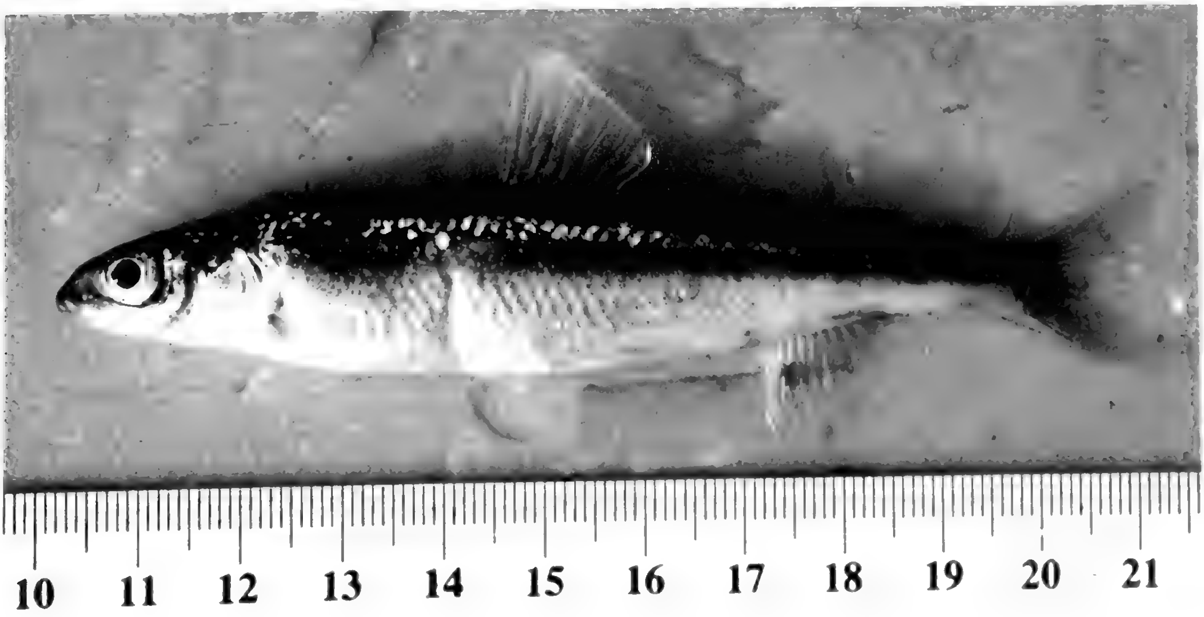

FIGURE 2. Pygmy Whitefish (*Prosopium coulteri*) captured in Bluefish Lake, Northwest Territories, 2012.

the shortest ray was split at the base, it was counted as a single ray.

After morphometric and meristic measurements were completed, specimens were cut ventrally, and the body cavity was examined for sex determination. When ovaries were found intact, they were removed. Fecundity was determined by counting eggs under a Leica ES2 dissection scope. Six eggs from each of three females were measured. All fish were subsequently re-frozen and archived.

We compared our morphological and biological characteristics to Coregonidae descriptions (McPhail and Lindsey 1970; Scott and Crossman 1973; McPhail 2007*), paying closest attention to features unique to Pygmy Whitefish and to *Prosopium* species. The Pygmy Whitefish is often confused with juvenile Mountain Whitefish (*Prosopium williamsoni*) or Round Whitefish (*Prosopium cylindraceum*).

Water temperature (° C), dissolved oxygen (mg/L), conductivity (µS/cm) and pH were recorded at the location and depth of the gillnet. An Ekman model E411196B12 bottom substrate retriever (Wildco, Yulee, Florida) was used to obtain bottom sediment at the sampling location. The bottom sediment sample was obtained from a single grab, described, and archived.

Results

Six individual Pygmy Whitefish, five females and one of unknown gender, with distinct stages of maturity were captured and examined. For general overall appearance, see Figure 2.

Description

Body small, fusiform, and streamlined; to 118 mm FL. Lumbar region moderate (15–19.5% of standard total length (STL). Caudal peduncle elongate (15.2–18.2% of STL) and narrow (6.3–7.1% of STL), body shallow, but variable (18.5–22.9% of STL). Dorsal aspect of head moderately to highly convex in profile (i.e., straight line from the premaxilla to the occipital bone). Head depth shallow (37.6–47.2% of head length [HLL]). Mouth slightly subterminal; maxillary short in length (24.5–31.2% of HLL) to near middle of eye and narrow (6.9–10% HLL). Eyes mid-set (preorbital length 20–22.6% of HLL), typically centred on the head along or slightly above midline of body. Eye diameter moderate (27.3–31.1% of HLL). Interorbital distance moderate (19.5–24.7% HLL). Gill raker number low, 16–18: 6–7 on upper arch and 10–11 on lower arch. Gill raker length short (3.2–4.7% of HLL), a distinguishing feature for this species. Dorsal fin moderate in length (10–11.8% of STL) and height (15.5–18.3% of STL); outer margin of dorsal fin angular; rays 9–10. Anal fin short at base; rays 9–11. Caudal fin forked and tips angular. Pectoral fins short and outer margin slightly concave; rays variable, 14–16. Pelvic fins short; origin below the second or third branched dorsal rays; rays 10–11; pelvic axillary process present. Adipose small. Lateral line complete, 54–60 scales. See Tables 1 and 2 for mean morphometric measurements and meristic counts.

Colouration

Live specimens generally silver with brownish dorsal colouration extending ventrally to two or three scale rows above the lateral line. Numerous parr marks present along lateral line and smaller blotches visible along dorsal surface. Anteriorly pigmented mandible and maxilla; paired fins immaculate or yellowish. Caudal fin lightly pigmented. Anal fin immaculate.

TABLE 2. Meristic counts for six Pygmy Whitefish (*Prosopium coulterii*), five females and one unknown gender, at Bluefish Lake, Northwest Territories.

Meristic count	Mean number
Dorsal rays	10.00
Anal rays	10.83
Pectoral rays	15.00
Ventral rays	10.20
Upper gill rakers	6.67
Lower gill rakers	10.17
Lateral line scales	56.17

TABLE 1. Morphometric measurements of six Pygmy Whitefish (*Prosopium coulterii*), five females and one unknown gender, at Bluefish Lake, Northwest Territories.

Measurement	Mean, mm	Measurement	Mean, mm
Trunk length	114.17	Caudal peduncle depth	6.55
Fork length	105.33	Interorbital length	5.03
Standard length	98.83	Maxillary length	6.01
Preorbital length	4.84	Maxillary width	1.99
Orbital length	6.91	Pectoral fin length	16.35
Post orbital length	11.26	Pelvic fin length	15.51
Trunk length	22.91	Adipose length	8.15
Dorsal fin length	10.56	Middle gill raker length	0.89
Dorsal fin height	16.18	Lower arch length	9.26
Caudal peduncle length	16.62	Anal fin length	9.30
Head depth	9.65	Lumbar length	17.50
Body depth	20.69		

Reproductive state

Five of the specimens were females with developed gonads indicating that they were close to spawning. One was in the resting phase and gender could not be determined. Fecundity, measured as total egg number, was determined for three of the five females as 209, 211, and 217 eggs. Egg size ranged from 2.08 to 2.79 mm.

Taxonomic assessment

Based on scale size, low lateral line scale count, adult parr marks, low gill raker counts, snout proportions, size at maturity, low fecundity, and large egg size, the six specimens collected in Bluefish Lake during our 2012 survey were determined to be Pygmy Whitefish. Specimens are archived at Fisheries and Oceans Canada, Yellowknife.

Habitat data

The bottom substrate at the sampling station consisted of clay and organic debris. At the depth where the six Pygmy Whitefish were captured, water temperature was 5.3° C, dissolved oxygen 3.5 mg/L, conductivity 63 µS/cm, and pH 6.3.

Discussion

The capture of Pygmy Whitefish in Bluefish Lake represents only the second observation of this species in the Northwest Territories and the first report of their presence in the Great Slave Lake Basin. It is unclear which glacial refugium was used to recolonize Bluefish Lake. However, the Athabasca population is thought to originate from the Cascadia refugium; thus, it is possible that the Pygmy Whitefish of Bluefish Lake are most closely related to the Columbia River drainage group. (see Appendix I for meristic means of North American Pygmy Whitefish populations studied thus far.) Isolated and small populations of coregonids, such as the Bluefish Lake Pygmy Whitefish, are important from a conservation standpoint because populations are often small and are, therefore, more susceptible to extirpation by stochastic events. It is likely that the distribution data for Pygmy Whitefish are incomplete, possibly because collectors fail to collect this species (Eschmeyer and Bailey 1955), due to their small size and relatively deep depth of capture. They may also be misidentified as juvenile Mountain Whitefish or Round Whitefish where these species co-occur.

Acknowledgements

Funding and logistical support was provided by Northwest Territories Power Corporation. Numerous people provided much-appreciated feedback and comments on this project, especially Grant Clarke and Gary Ash of Golder Associates Ltd.

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Received 15 May 2013
Accepted 8 May 2014

APPENDIX I. Meristic counts for Pygmy Whitefish (*Prosopium coulteri*) from all study areas in North America.

	Mean number									
Drainage	Locality	Source	Latitude, ° N	Longitude, ° W	Gill rakers	Lateral line scales	Caudal peduncle scales	Dorsal fin rays	Anal fin rays	Pectoral fin rays
Chignik	Black Lake	McCart (1970)	56.456	158.991	14.06	61.54	17.54	11.25	11.81	15.19
Chignik	Chignik Lake (slr)	McCart (1970)	56.259	158.824	14.16	63.95	18.02	11.36	12.44	15.40
Chignik	Chignik Lake (dlr)	McCart (1970)	56.259	158.824	14.50	62.94	17.93	11.55	11.95	15.05
Chignik	Chignik Lake (hr)	McCart (1970)	56.259	158.824	19.21	61.44	16.00	10.15	12.21	15.07
Columbia	Blaeberry River	McCart (1970)	51.519	117.373	14.15	62.90	19.31	11.70	11.95	15.30
Columbia	Bull Lake	Eschmeyer and Bailey (1955)	48.251	115.857	16.71	60.70	18.50	11.83	12.57	15.89
Columbia	Kicking Horse River	McCart (1970)	51.259	116.723	14.66	61.75	18.75	11.58	12.00	14.33
Columbia	Kinbasket Lake	McCart (1970)	52.132	118.436	13.60	60.15	18.07	12.05	12.65	15.40
Columbia	Laird Creek	McCart (1970)	49.621	117.004	15.70	57.80	18.23	11.45	13.15	16.85
Columbia	Lake McDonald	Eschmeyer and Bailey (1955)	48.583	113.920	17.20	59.20	18.35	11.40	12.45	16.00
Copper River	Klutina Lake	Bird and Roberson (1979)	61.691	145.966	17.50	55.50	16.00	11.40	11.90	13.90
Copper River	Tazlina Lake	Bird and Roberson (1979)	61.858	146.490	15.30	56.60	16.30	11.00	11.40	13.90
Copper River	Tonsina Lake	Bird and Roberson (1979)	61.500	145.527	15.30	57.00	16.00	11.30	11.50	14.50
Fraser	Cluculz Lake	McCart (1970)	53.884	123.585	13.70	58.59	18.88	11.15	12.55	15.26
Fraser	McLeese Lake	McCart (1970)	52.407	122.296	15.80	54.95	18.63	11.75	11.90	14.70
Fraser	Moose Lake	McCart (1970)	52.962	118.936	13.75	61.60	18.48	11.80	12.70	15.20
Fraser	Yellowhead Lake	McCart (1970)	52.867	118.533	13.90	57.09	18.11	11.64	12.54	15.73
Knik	Lake George	Wiedmer *et al.* (2010)	61.280	148.480	17.67	58.17	15.83	10.33	10.50	15.17
Mackenzie	Dease Lake	McCart (1970)	58.633	130.038	17.50	56.10	16.15	10.85	11.25	13.60
Mackenzie	Finlay River	McCart (1970)	56.879	126.972	14.60	60.50	19.30	12.10	12.90	15.20
Mackenzie	Tacheeda Lake	McCart (1970)	54.719	122.511	14.47	56.57	19.00	11.60	12.20	15.80
Naknek	Brooks Lake	McCart (1970)	58.513	155.901	16.32	54.85	15.90	11.00	12.10	15.20
Naknek	Grosvenor Lake	McCart (1970)	58.684	155.222	17.10	55.70	15.33	10.44	12.30	14.70
Naknek	Naknek Lake (lr)	McCart (1970)	58.649	156.210	14.54	62.77	17.85	12.00	12.33	15.48
Naknek	Naknek Lake (hr)	McCart (1970)	58.649	156.210	17.33	55.37	15.62	10.77	11.80	15.40
Nushagak	Lake Aleknagik (lr)	McCart (1970)	59.367	158.893	13.46	71.57	19.91	12.11	12.80	14.51
Nushagak	Lake Aleknagik (hr)	McCart (1970)	59.367	158.893	15.82	56.88	16.18	10.43	11.72	15.63
Saint Lawrence	Lake Superior	Eschmeyer and Bailey (1955)	47.097	87.007	18.28	57.14	19.46	10.90	13.20	14.62
Skeena	Morice Lake	McCart (1970)	54.005	127.606	15.20	62.20	19.20	11.70	12.65	15.90
Skeena	Nilkitkwa Lake	McCart (1970)	55.241	126.374	13.70	61.15	18.85	11.80	12.40	15.95
Skeena	Tyhee Lake	McCart (1970)	54.657	126.925	14.30	61.90	19.20	11.10	11.70	15.25
Yukon	Chadburn Lake	McCart (1970)	60.643	134.947	19.00	54.29	17.00	11.00	11.43	15.14
Mackenzie	Bluefish Lake	This study	62.684	114.262	16.84	56.17	n/a	10.00	10.83	15.00

Source: Wiedmer *et al.* 2010; McCart 1970.

Note: Water bodies have one or several morphotypes with high or low numbers of gill rakers and sometimes associated with deep or shallow water habitat: dlr = deep water low rakered, hr = high rakered, lr = low rakered, slr = shallow water low rakered.

Diurnal and Nocturnal Activity Patterns of Invasive Wild Boar (*Sus scrofa*) in Saskatchewan, Canada

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Stolle, Kathryn, Floris M. van Beest, Eric Vander Wal, and Ryan K. Brook. 2015. Diurnal and nocturnal activity patterns of invasive Wild Boar (*Sus scrofa*) in Saskatchewan, Canada. Canadian Field-Naturalist 129(1): 76–79.

The Wild Boar (*Sus scrofa*) is invasive in western Canada and poses a significant ecological and socio-economic threat over much of the country. We sought to quantify their presence and to determine when they are most active and whether their activity patterns are influenced by group size. Digital trail cameras (n = 18) were placed in a stratified design in the four most dominant habitat types of central Saskatchewan, Canada, and activated between December 2011 and June 2013 for a total of 5715 trap-days. In 71 175 photographs, we obtained 22 individual visits of Wild Boars to the trail cameras. We found no differences in activity between night (1900–0700; 59% of all detections) and day (0701–1859; 41% of detections), and we did not detect any effect of group size. Ongoing monitoring will be required to determine changing activity patterns in response to changing hunting pressure as Wild Boar continue to expand across Canada.

Key Words: diurnal activity; nocturnal activity; Wild Boar; *Sus scrofa*; feral swine; invasive species; Saskatchewan; trail camera

Introduction

The Wild Boar (*Sus scrofa*), which is native to Eurasia, has been introduced into North America on several occasions (Witmer *et al.* 2003; Barrios-Garcia and Ballari 2012). It is a successful invader because it easily adapts to novel food sources, is highly fecund, and is vagile (Witmer *et al.* 2003; Barrios-Garcia and Ballari 2012). Wild Boar are known to cause considerable environmental and agricultural damage (Campbell and Long 2010; Barrios-Garcia and Ballari 2012) and spread disease (Witmer *et al.* 2003; Leiser *et al.* 2013).

Little is known about the Wild Boar in Canada, including spatial distribution, abundance, and activity patterns. Their naturalization followed their use in specialized livestock farms, which has a history of less than 35 years (Brook and van Beest 2014). What is apparent, however, is that they now exist in viable populations across the Canadian Prairies (Brook and van Beest 2014). Despite the imminent ecological and socio-economic threat they pose, management (or eradication) efforts remain at best ineffective, at worst some management efforts such as use of bounties likely help disperse animals widely and increase population growth. The challenge is further exacerbated by the confusing taxonomic of the species, where both domestic pigs (*S. scrofa domestica*) and Eurasian Wild Boar (primarily *S. s. scrofa* but may also include other subspecies) are both the same species and hybrids between these and other subspecies occur in the United States and likely also occur in Canada (Wilson and DeeAnn 2005). These hybrids may have even higher reproductive success but there is little information in Canada to clarify their taxonomy or the implications of the hybridization.

Our objective was to quantify the presence and activity patterns of this newly invasive species in Canada. In particular, we aimed to determine when Wild Boar are most active and whether their activity patterns are influenced by group size. We did this using a system of remote trail cameras. As Wild Boar are a relatively new species on the Canadian Prairies, we suspected that they exist at low densities, even though they are widespread in distribution (Brook and van Beest 2014).

Study Area

Our study area (275 km^2; 52°37'N, 104°51'W) is in central Saskatchewan, Canada, near the town of St. Breiux. It is part of the transition area from the Prairie Ecozone in the south to the Boreal Plains Ecozone in the north and is referred to as the Prairie Parklands. The area is a complex mix of annual cropland and perennial forage farmland intermixed with fragmented native deciduous aspen forest, grassland, and wetland. The study area is a part of the prairie pothole region of the Great Plains, which is characterized by thousands of shallow pothole wetlands. Human density is low in the rural landscape: 0.74 people/km^2 and 0.27 households/km^2. The only town in the study area, St. Brieux, has a population of 590 people (Statistics Canada 2011). Hunting of Wild Boar in the study area is unregulated by the province of Saskatchewan, and no population estimates or metrics of annual harvest are recorded.

Methods

Between December 2011 and June 2013, we deployed 18 HyperFire 900 camera units (Reconyx Inc., Holmen, Wisconsin, USA) in four dominant habitat types: deciduous forest (n = 5), grasslands (n = 4), pasture–croplands (n = 5), and wetlands (n = 4). Cameras were placed within 50 m of a preselected location determined by a stratified random design and along game trails or open space if present. Each unit was attached to a tree or fence post, 100 cm above the ground facing in the direction with the least amount of vegetation cover (no vegetation was cleared except for twigs and leaves less than 1 m from the camera lens). We did not place bait in the vicinity of the cameras as we wished to detect natural behaviour. We programmed all cameras at the normal sensitivity setting (three photos at 1-s intervals triggered by an animal passing across the passive infrared motion detector in each camera), as this was found to be reliable during test trials (unpublished data). The metadata associated with each photo included a unique number, the time of day, and date.

All photographs were screened to identify those that contained Wild Boar. Most photos were of native wildlife common in the study area. For each non-native Wild Boar photo, we recorded the observed group size. In many cases, multiple photos were taken of an animal at a camera over several seconds or minutes, so regardless of the number of photos taken, we defined one individual "visit" to a camera as being from the first appearance of the animal to its disappearance from the camera over a period of 15 minutes. The largest group size recorded during each visit was assumed to be the final group size.

We compared frequency of visits between expected (i.e., randomly distributed) and observed numbers of Wild Boar for each hour of the day using a χ^2 test, and compared observed group sizes using a Mann-Whitney *U*-test.

Results

Between December 2011 and June 2013, we obtained 71 175 photos (5715 trap–days, calculated as the total number of camera traps * the total number of days the cameras were deployed) (see Figure 1 for samples). Between August 2012 and June 2013, three trail cameras and/or their photo cards were stolen and some data

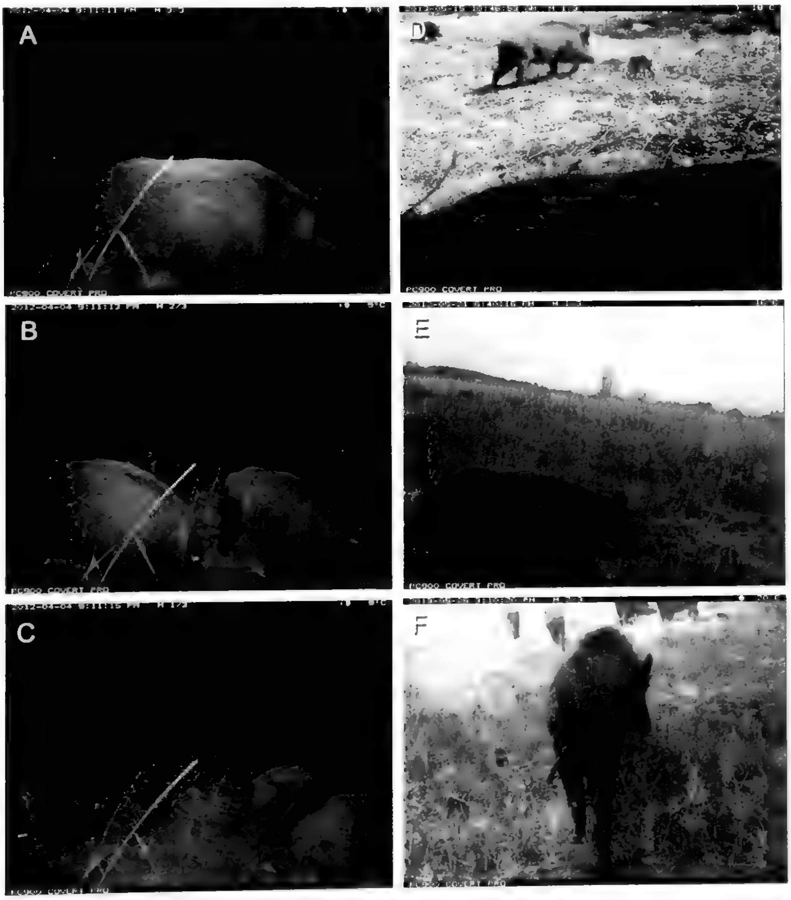

FIGURE 1. Photographs (A-F) taken by four trail cameras near St. Brieux, Saskatchewan, Canada, in 2012 and 2013 showing an adult female Wild Boar walking past the camera (A), with a litter of her young that are approximately 4 months old characterized by their size and lack of piglet striping of pale lines (B), followed by another litter of smaller 'squeaker' piglets approximately 3 weeks of age characterized as very small in size and having cream coloured stripes (C), all of these occurring at night, an image of a different group of Wild Boar during the daytime that includes young piglets (D), an image of a solitary animal in daylight (E), and a sounder of larger Wild Boar during the day (F).

were lost. We captured 22 individual visits of Wild Boar to trail cameras during the study period. In these visits we counted a minimum of 60 individual animals. In one instance, two Wild Boars were detected by a camera for approximately 2 h continuously. Another group joined the original group after the 2 h had elapsed. We considered the arrival of the second group to be a separate visit. More than half of the visits (59.1%) were of a single individual. Group size within a frame ranged from one to nine. The first Wild Boar was sighted on 15 December 2011 and the last on 20 May 2013. The number of visits varied considerably among months (Table 1).

TABLE 1. Sightings of Wild Boar (*Sus scrofa*) using trail cameras from December 2011 to June 2013 near St. Brieux, Saskatchewan, Canada.

Month	No. Boar visits	No. in Wetland	No. in Cropland	No. in Deciduous Forest
January	0	0	0	0
February	0	0	0	0
March	3	2	1	0
April	7	3	4	0
May	2	2	0	0
June	0	0	0	0
July	1	0	0	1
August	0	0	0	0
September	5	5	0	0
October	1	1	0	0
November	0	0	0	0
December	3	1	2	0

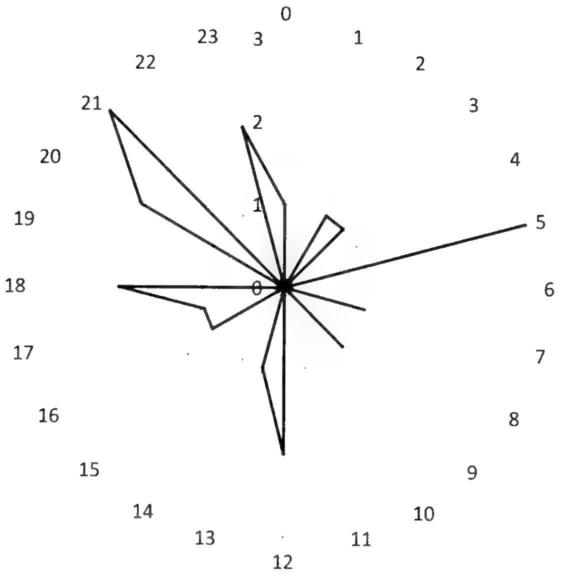

FIGURE 2. Time of visits of Wild Boar (*Sus scrofa*) at trail cameras from December 2011 to June 2013 near St. Brieux, Saskatchewan, Canada. The number of visits, from 0 to 3, is indicated by the distance from the centre of the circle; the hour of day is shown on the circumference.

There was no difference between expected (i.e., randomly distributed) and observed numbers of Wild Boar visits at each hour of the day ($\chi^2 = 7.0$, $P = 0.072$). Nocturnal (1900–0700) and diurnal (0701–1859) group sizes did not vary (Mann-Whitney $U = 51.5$, $P = 0.518$). The largest number of sightings occurred at 2400 h and half of the sightings (50%) occurred between 2000 and 2400; 59.1% of detections occurred at night (1900–0700; Figure 2). Wild Boar observations occurred in three habitats: wetland (64%), pasture–cropland (32%), and deciduous forest (4%).

Discussion

Observations of Wild Boar visits detected by trail cameras in central Saskatchewan, Canada, did not differ between day and night and group size, nor did visits vary significantly according to time of day. Although our cameras were active for 1.5 years, the number of Wild Boar visits to trail cameras was low. Because the efficacy of our cameras was high, it was unlikely that we failed to detect Wild Boar. Therefore, it seems that Wild Boar population densities are relatively low, at least in our study area. Nevertheless, after randomly distributing camera traps over a landscape, we managed to detect their presence and obtain photographs of successful reproductions in the wild (Figure 1) and one short series of continuous photos that capture a group (often called a 'sounder') led by an adult female (panel A, Figure 1) with one litter of juvenile piglets approximately 4 months old characterized by their size and lack of piglet striping of pale lines (panel B, Figure 1) and a second litter of 'squeaker' piglets approximately 3 weeks of age characterized as very small in size and having cream coloured stripes (panel C, Figure 1).

We do not know when Wild Boar first colonized our study area. However, it seems a sufficiently long period (i.e., generations) for them to have acclimated to local human presence by foraging and moving during both day and night. Wild Boar typically flee when approached by humans and are known to alter their activity patterns based on human activity (Singer *et al.* 1981). The distance to human dwellings also affects the activity patterns of Wild Boar (Keuling *et al.* 2008), although the density of human dwellings is very low in our study area.

Within their native range (e.g., Italy), Wild Boar are most active between 1700 and 0700 (Russo *et al.* 1997). Where boar are invasive, activity patterns vary; for example, in the United States, such variation exists among states (Campbell and Long 2010). Although hunting by humans is considered a key driver of increased nocturnal activity, some studies have found that hunting increases daytime activity while others report that nocturnal activity increases (Keuling *et al.* 2008). These observations of activity patterns are relevant to possible population control efforts, as visual detection of Wild Boar is more challenging at night and firearms regulations in western Canada do not allow discharge of a firearm at night. Thus, ongoing monitoring will be critical to understanding changes in activity patterns in response to management actions.

Acknowledgements

This work was funded by the University of Saskatchewan through the Natural Sciences and Engineering Research Council of Canada's President's Fund, the Cyril Capling Trust Fund, and a research start-up grant to R. K. B. We thank Caitlin Labach for logistic and field support. The Wildlife Ecology and Community Engagement Lab provided ongoing input and support. We especially acknowledge the many rural landowners in Saskatchewan who kindly gave us permission to set up cameras on their land.

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Received 30 April 2014
Accepted 4 November 2014

Mass Mortality of Northern Map Turtles (*Graptemys geographica*)

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Catrysse, Jordan, Emily Slavik, Jonathan Choquette, Ashley E. Leifso, and Christina M. Davy. 2015. Mass mortality of Northern Map Turtles (*Graptemys geographica*). Canadian Field-Naturalist 129(1): 80–83.

We report a mass mortality of Northern Map Turtles (*Graptemys geographica* [LeSueur, 1817]) on the north shore of Lake Erie, Ontario, Canada. Thirty-five dead adult females were recovered from a nesting area over a period of four weeks. Predation and boat strikes were both excluded as potential cause of death, but the actual cause could not be determined because of the poor condition of the carcasses. Other possible explanations for the mortality include poisoning, drowning, and infection with an unidentified pathogen. Mass mortality in long-lived species, such as turtles, can have long-term effects on population growth and is a cause for concern in a species at risk.

Key Words: Northern Map Turtle; *Graptemys geographica*; mass mortality; Lake Erie; Ontario; Canada

Introduction

In summer 2012, we documented a mass mortality of mature, female Northern Map Turtles (*Graptemys geographica* [LeSueur, 1817]) at a marsh–dune complex on the north shore of Lake Erie, Ontario, Canada. The exact location is withheld at the request of the permitting authority (Ontario Ministry of Natural Resources and Forestry). Location information can be obtained by written request to the Ontario Natural Heritage Information Centre (2nd Floor North Tower, 300 Water Street, Peterborough, Ontario K9J 3C7).

The Northern Map Turtle is listed as a species at risk in Canada; the Committee on the Status of Endangered Wildlife in Canada lists it as "Special Concern" (COSEWIC 2012). Thus, high, unexplained mortality in this species is cause for concern, and high mortality among mature females can have an especially long-lasting impact on long-lived species, such as turtles (Brooks *et al.* 1991). In this note, our goal is to make the details of this mortality available to other researchers who may encounter a similar event.

The first carcasses were found during surveys of a turtle nest site (a sandy beach) that we were monitoring from Monday to Saturday from late May to early July in the course of an ongoing conservation project. Six dead Northern Map Turtles were found between 17 June to 6 July 2012, near or just above the water line. Five of these carcasses were adult females; the sixth could not be sexed with certainty. Two had small tooth-marks on the shell that were not severe enough to cause death, but may have been left by scavengers, and two were in an advanced state of decomposition. The last two were found freshly dead (external tissue showed no signs of decomposition) with no obvious injuries to the skin or shell (Figure 1 a,b). Unfortunately, these carcasses were not sent for analysis, as the deaths appeared to represent incidental, natural mortality at the time. Daily, intensive monitoring of the nesting area ended on 7 July 2012.

On 16 July 2012, J. C. walked along the beach at the nesting site and discovered two desiccated Northern Map Turtle carcasses in sandy dunes well above the waterline. On 17 July 2012, he returned to the nesting area and, on further searching in the dunes, he found 27 more carcasses, all distributed within 100 m of one another and all well above the waterline. We returned several days later to collect and examine these, and were able to relocate and examine twenty-five. All 25 were female, as determined by shell shape and a curved carapace length of 21.6–27.1 cm (Ernst and Lovich 2009). The shells were intact (Figure 1c), excluding boat propeller strikes as a cause of death. The significant amount of tissue remaining on these carcasses suggested that the deaths had likely occurred in summer 2012, while the desiccation of the tissues suggested that the deaths had occurred several weeks before discovery of the carcasses. The exact time of death could not be determined, but it potentially coincided with that of the previously recorded mortalities.

No other turtle species were found dead on the nesting site in 2012, and a similar survey effort at this site in 2010, 2011, and 2013 found no dead Northern Map Turtles. Incidental dead and dying map turtles have been observed at the site during surveys of nearby habitat (Scott Gillingwater, Species At Risk Biologist, Upper Thames River Conservation Authority, personal communication, 25.09.2014; C. M. D., unpublished data). Some of these were attributable to road mortality, boat collisions, or predation, but often the cause of death could not be verified. The 2012 event was the first sudden concentration of map turtle carcasses discovered at the nesting site. Thus, this event appeared to be an isolated occurrence. Unfortunately, we could not identify the cause of death, but the following are possible explanations.

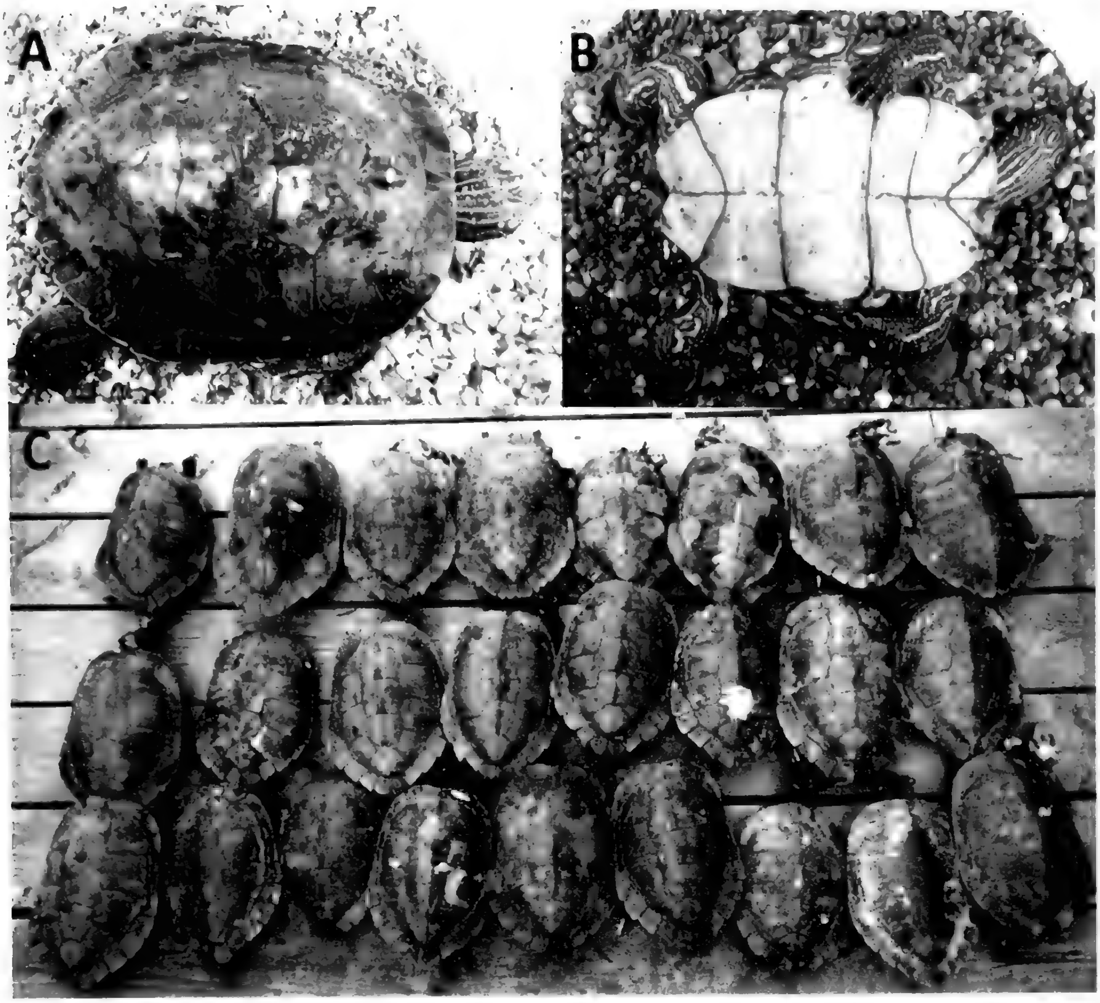

FIGURE 1. Dorsal (A) and ventral (B) views of a mature female Northern Map Turtle (*Graptemys geographica* [LeSueur, 1817]) found dead with no apparent injuries on 6 July 2012 and (C) desiccated carcasses of 25 of 29 Northern Map Turtles found dead from unknown causes on 16 and 17 July 2012 on the north shore of Lake Erie, Ontario.

Drowning in a commercial hoop trap or a fishing trawl net

Northern Map Turtles have never been caught in baited hoop traps used for research at this site despite their abundance, but they are caught in hoop traps elsewhere in Ontario (Larocque and Colotelo 2012; Larocque and Cooke 2012a,b). However, commercial fishing nets are employed adjacent to this nesting area, and female Northern Map Turtles form large aquatic basking aggregations at this site (C. M. D., personal observation). Northern Map Turtles typically dive when startled or disturbed; thus, the approach of a fishing vessel could cause a basking aggregation to dive into the path of an oncoming net in which the turtles could drown if they were not removed quickly. This scenario does not explain why six recently deceased turtles were found at the site early in the nesting season.

Predation during nesting

Nesting turtles are vulnerable to predation (Tucker *et al.* 1999), and some predators leave the shell intact. Crows (*Corvus brachyrynchos*) and ravens (*Corvus corax*) sometimes prey on turtles and tortoises, and they may do so by pecking into the abdomen above the tail so that the shell remains intact (Boarman 1997; Baxter-Gilbert *et al.* 2013). If the carcass is not found before decomposition begins, it can be difficult to identify this cause of death, but the carcasses that were found before desiccation showed no signs of such predation. Furthermore, four sympatric turtle species nest in comparable numbers at this site, and the predation scenario does not explain why mortality was apparently restricted to mature, female Northern Map Turtles.

A failed poaching attempt

We cannot rule out the possibility that the turtles were killed by humans, either intentionally or accidentally. However, we have no evidence to support this scenario.

Poisoning

This scenario requires a contaminated food source consumed only by mature female Northern Map Turtles. One possible option is botulism: poisoning caused by toxins produced by the bacterium, *Clostridium botulinum*. The toxin can accumulate in molluscs and gastropods, which are major food sources for both male and female Northern Map Turtles (Bulté *et al.* 2008; Richards-Dimitrie *et al.* 2013). Botulism is not uncommon in wildlife in the Great Lakes, but the Canadian Cooperative Wildlife Health Centre (CCWHC) received no reports of mortality of co-occurring species that consume molluscs or botulism-related waterfowl mortality in the area in 2012 (Lenny Shirose, CCWHC, Guelph, Ontario, Canada, 13.12.2013, personal communication). Botulism or poisoning from another source also does not easily explain the female bias in mortality, because both male and female Northern Map Turtles consume molluscs and gastropods (Bulté *et al.* 2008). Environmental contamination strong enough to kill 35 mature female Northern Map Turtles would likely also cause significant mortality of conspecific males and of other aquatic species.

An unidentified pathogen

The prevalence of emerging infectious diseases in wildlife appears to be increasing globally (Daszak *et al.* 2001). The degraded condition of the carcasses unfortunately precluded us from testing for pathogens, and this scenario requires significant inter-sex variation in pathogen susceptibility. Nevertheless, viruses and pathogenic fungi and bacteria are documented in some chelonid populations (Marschang 2011; Silbernagel *et al.* 2013) and can have a significant impact. Unusually high mortality of Blanding's Turtle (*Emydoidea blandingii*) and Painted Turtle (*Chrysemys picta*) was recently recorded at a site on Manitoulin Island (Jacqueline Litzgus, Professor, Laurentian University, personal communication; Mendler 2014), with the cause of death as yet unconfirmed. Seven of Canada's turtle species are listed under the federal *Species at Risk Act*, and infection of threatened populations with a lethal pathogen could have significant consequences for conservation of turtles in Canada.

Winterkill

Turtles that die during overwintering or shortly after emergence can sometimes take a long time to decompose, especially if the carcasses are located in cool areas. Anoxic conditions can trigger mass mortalities during overwintering; for example, a mass mortality of the Midland Painted Turtle (*Chrysemys picta marginata* Agassiz, 1857) occurred in 2000 at our study site, in a small pond that apparently became anoxic during overwintering (S. Gillingwater, 25.09.2014, personal communication), and Bleakney (1966) reports a similar mass mortality of Painted Turtles and Blanding's Turtles during the spring in Carleton County, which may also be attributable to winterkill.

We cannot rule out the possibility that some of the desiccated carcasses perished while overwintering and were moved posthumously. However, winterkill does not explain the freshly dead females found at the start of the nesting season, and it does not explain how the more desiccated carcasses arrived in the dunes, well above the waterline, following the nesting season.

At the Lake Erie site, eggs are laid in approximately 300 Northern Map Turtle nests each year (C. M. D., unpublished data based on 3 years of surveys). We do not have robust estimates of the size of this population and, therefore, cannot directly estimate the effect of the 2012 mortality event. However, assuming yearly nesting by females, it may represent the removal of approximately 10% of the reproductive females from this population in a single year. High mortality of mature individuals can have a significant, long-term impact on turtle populations, because turtles are slow to mature and do not exhibit density-dependent changes in reproductive output (Brooks *et al.* 1991; Congdon *et al.* 1993). It is critical that significant mortality events are monitored and investigated, and we hope that our observation will encourage further reporting of similar events when they are observed.

Acknowledgements

April Mitchell and Rebecca Carter assisted with monitoring of the nesting site in early summer 2012 and helped to record the first mortalities. Steven Evans and Mark Curry helped to collect the carcasses, and Elizabeth Hummel assisted with measurements. This event was recorded during a turtle conservation project supported by the Government of Ontario (Species at Risk Stewardship Fund for Ontario) and Wildlife Preservation Canada (Canadian Collection grant to C. M. D.). Fieldwork with Northern Map Turtles was conducted under research authorization from Ontario Parks and under Ontario Fish and Wildlife Scientific Collector's authorization 2012-1067721 and Ontario Ministry of Natural Resources Wildlife Animal Care Protocol 249 to C. M. D.

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Received 25 June 2014
Accepted 22 September 2014

The use of Ketamine-Xylazine and Ketamine-Medetomidine with and without their Antagonists Yohimbine and Atipamezole Hydrochloride to Immobilize Raccoons (*Procyon lotor*) in Ontario, Canada

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Allan, Mike R. 2015. The use of ketamine-xylazine and ketamine-medetomidine with and without their antagonists, yohimbine and atipamezole hydrochloride to immobilize Raccoons (*Procyon lotor*) in Ontario, Canada. Canadian Field-Naturalist 129(1): 84–89.

This study was undertaken to identify a drug combination that provided a suitable plane of anesthesia and pain suppression and reduced recovery time for minor surgical procedures in raccoons. In fall 2004, 40 wild Raccoons (*Procyon lotor*) were chemically immobilized using ketamine hydrochloride combined with either xylazine or medetomidine hydrochloride. Immobilizing treatments within and between drug types were compared in terms of induction, arousal and recovery times. The ketamine-xylazine (KX) group ($n = 20$) was given a combination of 20 mg/kg ketamine hydrochloride and 2 mg/kg xylazine hydrochloride by body weight, and the effects on induction, arousal and recovery time were recorded with and without the antagonist yohimbine hydrochloride. The ketamine-medetomidine (KM) group ($n = 20$) was given a combination of 5 mg/kg ketamine hydrochloride and 0.05 mg/kg medetomidine hydrochloride by body weight, and induction, arousal and recovery times were recorded with and without the use of the antagonist atipamezole hydrochloride. Administration of yohimbine hydrochloride at 0.1 mg/kg body weight to the KX group and atipamezole hydrochloride at 0.25 mg/kg body weight to the KM group produced considerably shorter arousal and recovery times in the KM group ($P = 0.016$). Mean arousal and recovery time with standard deviations ± (SD) for the KX group with yohimbine hydrochloride antagonist were 36.10 ± 10.69 and 94.2 ± 23.18 minutes; for the KM group with atipamezole hydrochloride antagonist, they were 7.95 ± 3.94 and 65.58 ± 14.75 respectively. At these doses, the KM combination reversed with atipamezole hydrochloride significantly reduced arousal and recovery times and resulted in a quality of anesthesia that would allow safe tooth and blood extraction in Raccoons.

Key Words: ketamine; medetomidine; xylazine; yohimbine; atipamezole; raccoon; *Procyon lotor*; chemical immobilization

Introduction

Field immobilization of wildlife using various chemical immobilizing agents has been well documented (Mech *et al.* 1965; Bigler and Hoff 1974; Gregg and Olson 1975; Deresienski and Rupprecht 1989; Belant 1991, 2005; Kreeger 1999; Gehrt *et al.* 2001). The Ministry of Natural Resources and Forestry (MNRF) wildlife research and monitoring section has an ongoing research and management program in response to rabies in multiple terrestrial carnivore species (Rosatte *et al.* 1993, 2009). This has led to the development of many research projects involving the chemical immobilization of Red Foxes (*Vulpes vulpes*), Striped Skunks (*Mephitis mephitis*) and Raccoons (*Procyon lotor*) using various tranquilizers, sedatives and dissociative anesthetic agents (Rosatte and Allan 2009; Rosatte *et al.* 2010). Immobilizing agents are necessary to allow safe handling of live-trapped animals to acquire morphological measurements, permit ear-tagging, apply a radio collar or perform minor surgical procedures such as premolar tooth extraction and blood collection. Tooth and blood collection are required to determine bait acceptance and rabies antibody level following oral rabies vaccine delivery to foxes, skunks and raccoons by hand or aircraft (Rosatte *et al.* 1993, 2010, 2011). Surgical procedures such as tooth and blood extraction require an adequate level of anesthesia, muscle relaxation and pain suppression. Ketamine alone will provide anesthesia, however muscle relaxation is dosage dependent and pain suppression requires the addition of an analgesic (Gregg and Olson 1975; Fuller and Kuehn 1983; Dzialak *et al.* 2002). Although the analgesic promotes good muscle relaxation and pain suppression it may prolong recovery time (Dzialak *et al.* 2002). Combining ketamine with a tranquilizer or sedative has been observed to offset the convulsions often observed when using this drug and provide better muscle relaxation and analgesic properties in some wildlife species (Ramsden *et al.* 1976; Fuller and Kuehn 1983; Seal and Kreeger 1987; Dzialak *et al.* 2002; Rosatte and Allan 2009). Not all tranquilizers are reversible but recovery time can be reduced by reversing sedatives using alpha-2 antagonists. Improvements in recovery time have been observed after administering yohimbine hydrochloride to reverse the effects of xylazine in Mule Deer (*Odocoileus hemionus*), White-tailed Deer (*Odocoileus virginianus*), Elk (*Cervus elaphus*), Polar Bears (*Ursus maritimus*) and Raccoons (Jessup *et al.* 1983; Mech *et al.* 1985; Ramsay *et al.* 1985; Deresienski and Rupprecht 1989; Rosatte 2007). Ideally, field operations require the safe release of animals following immediate recovery from anesthetic, hence, the need for a drug combination that immobilizes animals safely and reduces recovery time.

Medetomidine hydrochloride is an alpha-2 agonist that is more potent and 10 times more selective than xylazine hydrochloride; it actively attaches to sites at a ratio of 1620:1 compared with 160:1 for xylazine (Sinclair 2003). Medetomidine hydrochloride has been administered to Coyotes *(Canis latrans)*, Red Foxes and Raccoons with reasonable success in animal handling procedures such as measurements and innoculations (Baldwin *et al.* 2008). When combined with ketamine hydrochloride, medetomidine hydrochloride has been used effectively to chemically restrain a variety of other wildlife species (Tsuruga *et al.* 1999; Haulena and Gulland 2001; Fernandez-Moran *et al.* 2001; Dzialak *et al.* 2002; Bieglböck and Zenker 2003; Fournier-Chambrillon *et al.* 2003; Belant 2005; Robert *et al.* 2012). The effects of this combination can be quickly reversed using the antagonist atipamezole hydrochloride and this procedure has demonstrated smooth induction, good immobilization and rapid recovery in Eurasian Otters, (*Lutra lutra)* European Mink (*Mustela lutreola)*, Polecat (*Mustela putorius*) (Fernandez-Moran *et al.* 2001; Fournier-Chambrillon *et al.* 2003) and Raccoons (Robert *et al.* 2012). The ketamine-medetomidine combination has been reported to provide a good level of anesthesia and muscle relaxation and a better quality of surgical anesthesia than a ketamine-xylaxine combination in rabbits (Henke *et al.* 2005).

The purpose of this study was to compare KX and KM drug combinations with and without antagonists and their effects on induction, arousal and recovery times. I also evaluated which drug combination meets the pain suppression and muscle relaxation requirements during minor surgical procedures and demonstrates the shortest recovery time in Raccoons.

Methods

During the week of 6–10 September, as part of MNRF rabies research operations in the Niagara region (43°05'N, 79°05'W), Raccoons were randomly trapped using number 108 and 106 Tomahawk live traps (Tomahawk Live Trap Company, Hazelhurst, Wisconsin, USA), baited with sardines in soya oil. Animals were transported by pick-up truck and housed at the Codrington Research Facility, Codrington, Ontario, Canada (44°08'N, 77°48'W). Animals were divided into two groups of 20 animals that were similar in terms of age and sex. The KX group included four adult males, five adult females, six juvenile males and five juvenile females. The KM group included five adult males, five adult females, four juvenile males and six juvenile females. Each animal was transferred from the trap into a plywood nesting box (60 cm × 58 cm × 30 cm) with access to an individual wire cage holding pen (152 cm × 60 cm × 60 cm) and allowed to acclimatize for 1 week before treatment. Raccoons were fed 170 grams per day of fox maintenance feed, (Martin Mills Inc., and Elmira Ontario, Canada) and provided with water on a daily basis. Animals were not fed on the morning of the experiment and feeding was postponed until all animals had recovered fully from the anesthetic. Raccoons were captured in their nesting boxes using a 4-foot snare pole (Ketch-all San Luis Obispo, California USA) and placed into a Tomahawk 108 live trap and weighed to the nearest tenth of a kilogram minus the trap weight. Mean ambient air temperature was calculated using hourly data from Environment Canada from 1000 to 1600 EST (Environment Canada 2014) which included the time frame of the treatments.

Treatment one commenced on 20 September 2004. The KX group was immobilized using a 10:1 ratio of the two drugs by body weight: 20 mg/kg ketamine hydrochloride (Rogarsetic 50 mL, 100 mg/mL, Pfizer Canada Inc., Pointe-Claire, Quebec, Canada) and 2 mg/kg of xylazine hydrochloride (Anased 50 mL, 100 mg/mL, Novopharm Ltd., Toronto, Ontario, Canada). Raccoons were restrained in their nesting boxes using a plunger squeeze technique and given an intramuscular injection into the quadriceps muscle of the hind limb using a handheld 3 mL syringe with 22 gauge needle. Mean ambient air temperature was 19.8°C.

On 21 September 2004, the KM group was immobilized 100:1 ratio of the two drugs by body weight; 0.05 mg/kg ketamine hydrochloride and 0.050 mg/kg medetomidine hydrochloride (Domitor, 10 mL, 1.0 mg/mL, Novartis Animal Health Canada Inc. Mississauga, Ontario, Canada). Mean ambient air temperature was 23.9°C.

Treatment two began on 5 October 2004 with the KX group receiving the same drug combination as in the first treatment. Approximately 18 minutes post-induction the animals received the antagonist yohimbine hydrochloride (Lloyd Yobine, 20 mL, 2 mg/mL (Teva Canada, Scarborough, Ontario, Canada) at a dosage of 0.1 mg/kg. Mean ambient air temperature was 10.1°C

On 6 October 2004, the KM group was immobilized using the same dose as in the first treatment followed by intramuscular injection of the antagonist atipamezole hydrochloride (Antisedan, 10 mL, 5.0 mg/mL, Novartis Animal Health Inc.) at a dose of 0.25 mg/kg 18 minutes post-induction. Mean ambient temperature was 16.4°C.

Injection, induction, arousal and recovery times were recorded for individual animals in each group. Injection time was recorded as the time following injection: induction time was measured as the time following injection to lack of responsiveness to tactile stimuli (palpebral reflex and toe pinch). Arousal time was recorded as time from induction to the animal's first attempt to raise its head from the floor of the holding pen. Recovery time was recorded as the time from arousal to lack of ataxia in the hind limbs. Antagonists were injected on average 18 minutes after induction to simulate the length of a minor surgical procedure. All animals were handled according to MNRF Animal Care Committee protocol #04-91.

Data analysis

Induction, arousal and recovery times were entered into Excel (windows version 2000, Microsoft, Redmond, Washington, USA) and exported into Statistica® version 6.0 (Statsoft, Tulsa, Oklahoma, USA). Before analysis, log transformation of all data was completed to establish normality and achieve homogeneity of variances. Data for one animal from the KM group were excluded during analysis as normality could not be attained because of an overly long recovery time. Differences in induction, arousal and recovery times were tested within and between drug combinations for the two treatments. A MANOVA was used to detect differences within and between the KX and KM groups. Differences between age and sex classes were not examined as sample sizes were considered too small, i.e., low power increased the chance for Type II error (Zar 1999). Mean value statistics, standard deviation and range for each group were calculated. Alpha was set at $P = 0.05$.

Results

Analysis of covariance showed that body weight had no significant effect on induction, arousal or recovery time ($P > 0.05$).

During treatment one, when no antagonist was used and comparisons between induction, arousal and recovery times were made between the KX and KM drug types, shorter induction, arousal and recovery times were observed for the KX drug combination ($F_{(2, 76)} = 7.31$, $P = 0.001$).

In treatment two, when antagonists were used, induction time for the KX group was twice as long as in treatment one ($P = 0.026$). Arousal and recovery times were significantly shorter following administration of yohimbine hydrochloride ($P < 0.001$ and $P = 0.015$) respectively and significant differences were found for induction, arousal and recovery times when comparing treatments within the KX group ($F_{(2,76)} = 10.74$, $P < 0.001$). For the KM group, when the antagonist atipamezole hydrochloride was used, shorter arousal and recovery times were observed compared with treatment one ($P < 0.001$) with no differences observed between induction times, and significant differences were observed between treatments for induction, arousal and recovery times ($F_{(2, 74)} = 22.72$, $P < 0.001$).

Comparing drug combinations, no significant differences were observed regarding induction time. Raccoons in the KM group demonstrated significantly shorter arousal and recovery times when given atipamezole hydrochloride compared with those in the KX group given yohimbine hydrochloride ($F_{(2, 74)} = 4.354$, $P = 0.016$). Differences in induction, arousal and recovery times within and between drug combinations are shown in Table 1.

Discussion

Variation in the length of induction time to induce anesthesia in raccoons was observed in the KX group between treatments. Poor induction may be attributed to the behavior of individual animals before immobilization and may be attributable to various biological or behavioural influences. Some animals were very calm during injection while others displayed aggression. Animals were restrained in nesting boxes by quickly lifting the lid and pinning the Raccoon using a plunger type squeeze technique. Although Raccoons were often restrained quickly, more aggressive animals took longer to restrain. Prolonged restraint coupled with the aggressive and agitated state of these animals may be the reason for some of the variation observed in induction times between the two treatments in the KX group. Aggressive behavior has been known to affect drug absorption and result in failure to achieve optimum sedation (Sinclair 2003). Because I did not record animal behavior for every injection I cannot say whether aggressive behavior affected induction time in the KX group.

Repeated exposure to drugs is thought to prolong induction and recovery times in some mammals. This has been observed in seals and raccoons, where repeated exposure to ketamine and medetomidine increased induction time (Field *et al.* 2002; Wheatley *et al.* 2006; Robert *et al.* 2012). In this study, an increase in induction during the second KX treatment was observed; however, no significant difference in induction time was observed in the KM group. Although the increased induction time in the KX group might be a result of drug tolerance, it could also be related to other biological or ambient conditions.

A study in Quebec observed longer induction time for Raccoons administered KM in the fall, indicating lower ambient temperature and increased body fat may affect drug absorption at this time of year (Baldwin *et*

TABLE 1. Induction, arousal and recovery times of Raccoons (*Procyon lotor*) administered ketamine hydrochloride combined with either xylazine hydrochloride or medetomidine hydrochloride without and with the antagonists yohimbine hydrochloride and atipamezole hydrochloride respectively.

Drug combination	*n*	Induction time mean ± SD (range)	Arousal time mean ± SD (range)	Recovery time mean ± SD (range)
KX without YH	20	3.6 ± 2.54 (1–10)	55 ± 16.06 (28–95)	113.65 ± 26.41 (73–160)
KX with YH	20	6.25 ± 4.84 (2–19)	36.10 ± 10.69 (18–60)	94.2 ± 23.18 (61–145)
KM without AH	19	6.74 ± 3.81 (2–18)	71.73 ± 24.23 (43–147)	132.1 ± 37.24 (75–201)
KM with AH	19	7.63 ± 4.68 (2–17)	7.95 ± 3.94 (3–15)	65.58 ± 14.75 (37–99)

Note: AH = atipamezole hydrochloride, SD = standard deviation, YH = yohimbine hydrochloride.

al. 2008; Robert *et al.* 2012). In my study, the mean ambient temperature was almost 10°C cooler during the second treatment which might explain the much longer induction time observed in the KX group. Mean ambient temperature differences for the KM group was 7.5°C and no differences in induction time were observed between treatments in that group suggesting that there may be a temperature threshold that delays induction however this was beyond the scope of this study.

Larger body mass has been known to cause slower induction and recovery times in the North American Porcupine (*Erethizon dorsatum*) (Morin and Berteaux, 2003); however, based on the analysis of covariance in this study, weight had no impact on induction, arousal or recovery times in Raccoons. The restraining technique used in this study provided clear access to the quadriceps muscle allowing a good site for intramuscular injection. Therefore differences in induction time are not likely attributable to faulty injection. Thus reasons for the differences in induction between treatments in the KX group remain unclear.

In the absence of an antagonist, KX allows shorter induction, arousal and recovery times than KM in Raccoons. This has also been observed in Alpine Marmots (*Marmota marmota*) where induction times were not significantly different, but arousal and recovery times were significantly longer in the KM group (Bieglböck and Zenker 2003).

For the KX group in this study, shorter arousal and recovery times were expected following intramuscular injection of the antagonist yohimbine hydrochloride. Xylazine attaches to the presynaptic adrenoreceptors, reducing the release of norepinephrine. Yohimbine reverses the xylaxine hydrochloride at the presynaptic adrenoreceptors, thus increasing the release of norepinephrine (Langer 1980; Kreeger *et al.* 1987). Reversing the effects of xylazine hydrochloride with yohimbine via intramuscular, sublingual or intravenous administration has been observed to reduce recovery times in a number of mammalian species (Jessup *et al.* 1983; Mech *et al.* 1985; Ramsay *et al.* 1985; Kreeger *et al.* 1987; Deresienski and Rupprecht 1989; Rosatte 2007). Although sublingual, femoral or jugular intravenous injection may be feasible in larger mammals, it is less desirable in operations involving large numbers of meso-carnivores where veins are smaller and where intramuscular injection is more practical (Rosatte *et al.* 2009).

Medetomidine hydrochloride induces sedation for up to 70–90 minutes when administered intramuscularly at doses of 0.03 mg/kg by weight in dogs and cats. Higher doses > 0.080 mg/kg will not increase sedation, but will prolong recovery (Sinclair 2003). In my study, drug dosages of 0.05 mg/kg medetomidine hydrochloride and 5 mg/kg ketamine hydrochloride were used on Raccoons and sedation periods averaged 124.36 minutes without administration of the antagonist atipamezole hydrochloride. Longer recovery times averaging 199.4 minutes were observed in the Fisher (*Martes pennanti*) using slightly higher doses of medetomidine hydrochloride (0.07 mg/kg) and lower ketamine hydrochloride doses averaging 3.7 mg/kg for males and 3.6 mg/kg for females (Dzialak *et al.* 2002). In the absence of an antagonist, perhaps a lower dose of medetomidine hydrochloride could be considered for non-surgical operations to reduce recovery periods in Raccoons and Fishers.

Reversing the KM drug combination using atipamezole hydrochloride resulted in shorter arousal and recovery times for Raccoons in this study. Similar results have been observed in Polar Bears, Sika (*Cervus Nippon*), Eurasian Otter, European Mink, European Polecat and Raccoons (Cattet *et al.* 1997; Tsuruga *et al.* 1999; Fernandez-Moran *et al.* 2001; Fournier-Chambrillon *et al.* 2003; Robert *et al.* 2012). This was expected as atipamezole hydrochloride fully antagonizes the sedative and behavioural effects of medetomidine hydrochloride when administered at four to six times the medetomidine hydrochloride dose (Sinclair 2003). In this experiment, medetomidine hydrochloride antagonized at five times the atipamezole hydrochloride dosage (0.25 mg/kg) and Raccoons were walking shortly after arousal but demonstrated limb ataxia likely attributable to the residual ketamine. Ketamine hydrochloride has no known antagonist. Although administering yohimbine hydrochloride has been reported to shorten arousal times in the Gray Wolf (*Canis lupus*) and Domestic cat (*Felis catus*), no improvement was observed in walking times (Hatch *et al.* 1983; Kreeger and Seal 1986*a*; Kreeger and Seal 1987). The shorter arousal times observed in the KM group may be attributed to the lower dose of ketamine (5mg/kg compared with 20mg/kg in the KX group) and the intramuscular administration of atipamezole hydrochloride. Given that yohimbine hydrochloride shortens arousal time in wolves and cats, and atipamezole hydrochloride is also an alpha-2 antagonist, it is likely that the atipamezole hydrochloride is stimulating the nervous system of Raccoons in a similar manner and contributing to shorter arousal times in the KM group.

The KM drug combination requires significantly less ketamine hydrochloride than the KX drug combination for the chemical immobilization of Raccoons. Given that ketamine is a restricted drug in Canada, lower volumes are more likely to be approved and are easier to track and maintain by the biologist. KM has been used successfully in live-animal capture programs in MNRF rabies control programs. In large-scale field operations, we successfully immobilized and performed minor surgical procedures on over 1200 Raccoons and Striped Skunks using 550 mL of ketamine, averaging less than 0.5mL of ketamine per animal (Rosatte *et al.* 2009). For the same number of animals, we would have used four times the volume of ketamine if it was combined with xylazine hydrochloride, a difference of $1300 in cost of ketamine alone.

KM and the antagonist atipamezole hydrochloride is a better drug combination for reducing recovery in Raccoons compared with KX antagonized with yohimbine hydrochloride. No mortalities or adverse reactions were observed indicating that the drugs are safe at these doses. Smooth induction, good muscle relaxation, rapid arousal and recovery combined with a wide safety margin make KM a good replacement for KX for performing tooth and blood extraction procedures on Raccoons.

Acknowledgements

This project was funded by the Ontario Ministry of Natural Resources and Forestry Rabies Research and Development Program and approved by Dr. J. Chris Davies, Manager of Wildlife Research and Monitoring Section. I thank Dr. Graham Crawshaw and his associate Dr. Mats Bertelson for sharing their knowledge and training in the areas of chemical immobilization of mammals and their recommendations for conducting a trial on raccoons. I also thank Scott Taylor and Vaughan Jamieson for their animal husbandry expertise and assistance during the experiment; Scott Norton and the Niagara trapping staff of the Rabies Research and Development Unit for their assistance in capturing and delivering the animals for the trial; Linh Nguyen, part-time professor at Trent University for his advice, knowledge, patience and time in helping me with the statistical analyses; Dr. Dennis Murray of Trent University, Dr. Rick Rosatte and Beverly Stevenson of Ministry of Natural Resources and Forestry for providing comments and suggestions and reviewing the manuscript; and associate editors and reviewers of the Canadian Field Naturalist for their useful comments and suggestions for improving this manuscript.

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Received 29 July 2014
Accepted 7 November 2014

A Tribute to John Montague Gillett, 1918–2014

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Haber, Erich. 2015. A tribute to John Montague Gillett, 1918–2014. Canadian Field-Naturalist 129(1): 90–96.

John Montague Gillett (Figure 1), or "Jack," as he was called by everyone, was born in Ottawa on 26 November 1918, the only child of Elizabeth and John C. Gillett, both of whom came from large families in England. Elizabeth left England as a lady's handmaiden on a passenger liner bound for the United States. She subsequently moved to Ottawa, and John joined her there. John was a machinist and Elizabeth worked as a chef in her early career.

Jack grew up in the Westboro area of Ottawa, where he explored with like-minded friends such as Lloyd Francis, former member of the Canadian Parliament and Speaker of the House. Jack and friends spent their holidays at Constance Bay and occasionally would cross the Ottawa River in a rowboat equipped with a sail. They would climb the escarpment ("the mountain") in an area that would become part of Gatineau Park, Quebec. For thrills, they would also dive into the turbulent waters at Hog's Back Falls, Ottawa.

Jack completed his secondary school studies at Glebe Collegiate Institute in 1937. At Glebe, he also learned shorthand and typing. This bode well for Jack because, while working part time after school cleaning up in the chemistry lab, he was asked by a staff member to type out his doctoral thesis, which was on a botanical topic. This kindled in him a lifelong interest in botany and taxonomy.

Jack joined the Royal Canadian Air Force and served both in Canada and England between November 1940 and September 1945. He initially wanted to be a pilot and trained to fly fighter planes while at the Gander Airfield in Newfoundland. However, after episodes of blacking out during training, Jack became a mechanic instead. When he was transferred to the Kirmington Airfield (Humberside International Airport), Lincolnshire, England, Jack worked as a radar mechanic on Lancaster Bombers. Unfortunately, this resulted in a partial hearing loss from the noise of the bomber engines that were being serviced.

Following his military service, Jack enrolled in biology at Queen's University, Kingston, Ontario (1945–1949). He used his veterans' allowance to fund his initial postsecondary education. In the course of his studies at Queen's, he served as an undergraduate assistant in general biology (1946–1947). During the summers of 1946–1948, Jack returned to Ottawa as a summer student planting trees in the Arboretum and working in the herbarium of the Division of Botany and Plant Pathology at the Central Experimental Farm (CEF), Agriculture and Agri-Food Canada (AAFC). In the summer of 1948, he was sent to Churchill, Manitoba, to assist in a northern survey project conducted for the Defence Research Board. After graduating from Queen's in May 1949 with an honours B.A. (biology, chemistry), Jack joined the staff at the CEF herbarium. In the fall of 1949, Jack took leave from his position and began studies for his doctoral thesis on the genus *Gentianella* at the Missouri Botanical Garden under the supervision of Robert E. Woodson. While conducting his research there and majoring in plant taxonomy and morphology, Jack also served as a herbarium assistant (1949–1951).

FIGURE 1. John M. Gillett, 1974. Photo courtesy of the Canadian Museum of Nature.

Jack received his Ph.D. on 8 May 1952 from Washington University, St. Louis, after completing his thesis entitled: *A Revision of the North American Species of* Gentianella (Figure 2). That same summer, he returned

FIGURE 2. Windmill Fringed Gentian, a species studied by Jack Gillett and originally treated as *Gentianella detonsa* (Rottboll) G. Don ssp. *nesophila* (T. Holm) J. M. Gillett. This was later transferred to the genus *Gentianopsis*. Photo: D. Brunton, Hawkes Bay, Newfoundland, Canada, 4 August 2014.

to Ottawa and began the first of his many field surveys (Cody *et al.* 1986), which included the vicinity of Marmora, Ontario (1952); along the proposed route of the St. Lawrence Seaway, with W. G. Dore (1952, 1953); Crater Lake, Labrador, in connection with the National Geographic Society and the Royal Ontario Museum (1953); Florida, with W. M. Bowden (1954); the area around Québec City (1955); southern Ontario (1957); Churchill, Manitoba (1958), to prepare for an International Botanical Congress field trip for which he was host (1959); along the Alaska Highway in northern British Columbia, southern Yukon, and the Ogilvie Mountains with J. A. Calder (1960); southern Ontario for studies on legumes (1961); western Canada and United States (1962, 1963, 1964, 1966, 1970); and a floristic study of Gatineau Park, Quebec (1967, 1968).

Jack's early surveys, checklists, and plant collections serve as useful tools that now provide an insight into floristic changes that have occurred in areas explored decades ago. One such important survey conducted with Bill Dore in 1952–1953 along the proposed St. Lawrence Seaway, provides an in-the-nick-of-time inventory of a significant ecological corridor that no longer exists. This inventory remains as the most comprehensive ever conducted in southeastern Ontario.

Jack was an amiable field companion according to one of his colleagues from the former Plant Research Institute, AAFC (Ted Mosquin, personal communication). He recalled with much affection his time with Jack exploring the mountains of the American Great Basin collecting clovers (*Trifolium* spp.). Jack was a light-hearted and fun-loving companion on botanical collecting trips. He would take great delight when encountering a species he had not seen before, especially of rare native clovers, and would let out a boyish shriek of joy. At times of considerable risk, walking along the edge of a cliff, a steep slope, or in areas of bear signs, Jack would exclaim, "Never fear, Bullwinkle is here." This is in reference to an early animated TV show featuring Bullwinkle, a moose with large antlers, and his friend Rocky, a flying squirrel. Ted also benefitted, as others have, from Jack's helpful nature in providing assistance with plant identifications. He was always keen to chat with botanists and to provide encouragement and advice.

In 1972, Jack left the Plant Research Institute at CEF to become a curator and head of the vascular plant section of the herbarium at the National Museum of Natural Sciences (now Canadian Museum of Nature). In his new role, he undertook to reorganize species alphabetically within genera rather than follow the existing scheme based on grouping species by presumed affinities. Over the course of his years at the museum, Jack continued his work on the local flora. This included preparing an extensive manuscript on the flora of Gatineau Park, which unfortunately was never published in its entirety. Several groups of plants from the manuscript, such as the clovers, asters, goldenrods, and violets, were published in *Trail & Landscape*, a quarterly newsletter of the Ottawa Field-Naturalists' Club. Jack also published a *Checklist of the Vascular Plants of the Ottawa-Hull Region*. The second, updated version of this checklist, revised with David White in 1978 (see bibliography), served, for decades, as an important tool for floristic work in the region and for landscape conservation and protection. Jack also continued with his taxonomic studies of various plant groups at the museum. He retired from the museum in 1983 (Figure 3), but maintained his affiliation as curator emeritus.

Jack was a "field biologist," who applied knowledge gained in the field to his systematic studies. This approach provided a better understanding of the species in nature and helped in the recognition of new taxa. In his work with gentians (Gentianaceae), Jack described two new subspecies: Pribilof Dwarf Gentian (*Gentianella tenella* (Rottbøll) Börner ssp. *pribilofi* J. M. Gillett); and Yukon Fringed Gentian (*Gentianopsis detonsa* ssp. *yukonensis* (J. M. Gillett)).

Among other genera Jack studied, he specialized, in particular, in clovers (*Trifolium* spp.). His contributions to this important group, which includes many economically important species, focused on North American species but also extended worldwide. Jack described three new species and three new subspecies that are currently still recognized for North America: Dedecker's Clover (*Trifolium dedeckerae* J. M. Gillett); Rollins' Clover (*Trifolium rollinsii* J. M. Gillett); Siskiyou Clover (*Trifolium siskiyouense* J. M. Gillett); Beatley's Clover (*Trifolium andersonii* A. Gray ssp. *beatleyae* J. M. Gillett); Cascade Clover (*Trifolium eriocephalum* Nuttall ssp. *cascadense* J. M. Gillett); Martin's Clover (*Trifolium eriocephalum* Nuttall ssp. *martinii* J. M. Gillett). (It is interesting, and potentially confusing, that another Gillett, unrelated to Jack (Jan B. Gillett, 1911–1985), has also published new species of clovers.) Jack also described as new the Great Lakes Wheatgrass (*Agropyron psammophilum* J. M. Gillett & H. Senn), which was subsequently transferred to the genus *Elymus* as a subspecies (*Elymus lanceolatus* ssp. *psammophilus* (J. M. Gillett & H. Senn) Á. Löve).

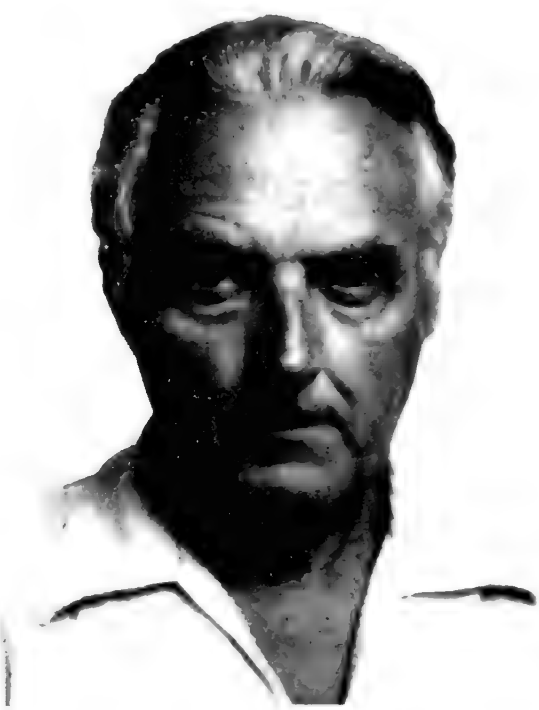

FIGURE 3. John M. Gillett, 1982. Photo provided by the Gillett family.

Over the years, Jack was a member of a number of scholastic and learned societies: Sigma Xi, International Association for Plant Taxonomy, American Society of Plant Taxonomists, the New England Botanical Club, the California Botanical Society, the Canadian Botanical Association, Société botanique du Québec, the Explorers Club of New York, and the Ottawa Field-Naturalists' Club (OFNC).

Jack was a long-time member of the OFNC, beginning in 1946 when he was a summer student at the CEF. He served on its council from 1958 to 1970 in various capacities, including treasurer, auditor, and chair of the Publications Committee. He also compiled a comprehensive index to the *Transactions of the Ottawa Field-Naturalists' Club* and to *The Ottawa Naturalist*. In 1996, Jack received the Anne Hanes Natural History Award from the OFNC. This was given for his outstanding contributions to knowledge of the natural history of the Ottawa Valley through publications and long service on the OFNC council, club field excursions, and his friendly and open nature to both professional and would-be botanists. In 2000, he was awarded honorary membership in the OFNC (Brodo *et al.* 2001).

Jack met his first wife, Gladys Isabel Proulx (of Aylmer, Quebec, 1927–2001), while playing tennis and being soundly trounced. Her tennis skills apparently made a lasting impression on Jack. They were married 1 September 1956. Jack and Gladys had two children, Peter (1958), who became a visual artist and resides in Toronto with his partner Alma Roussy, and Kimberley (1960). Kimberley (Burnett) is a retired chartered professional accountant (CPA, CA) living in Ottawa with her husband François Gouin (CPA, CA). Kimberley has a daughter, Shannon Burnett, a Toronto special effects make-up artist for film and TV, who is married to Michael Echlin, also a visual artist. Gladys died on 20 July 2001 after a long battle with hepatitis C, contracted from a blood transfusion.

Jack was a man of many interests. He played piano, both classical and show tunes, and collected stamps and minerals. His "rock collection" was sufficiently extensive that his neighbours constructed a "mineral garden" with his collection when his house was sold and the garage was emptied of its contents. Jack was highly curious and fascinated by diverse topics, ranging from quantum physics to the politics of light-rail travel. He loved trains of all kinds and studying languages. His bookcase contained many instruction manuals, including French, Latin, Italian, Spanish, Chinese, Cree, Inuit, and Russian. He could nap readily, anywhere, anytime, and loved skinny-dipping, picnics in cemeteries, garage sales, and Saturday house shopping. Rain or shine, with kids in the back seat, "professional house shoppers" Jack and Gladys would head out on their weekly Saturday tours. In 45 years, they never did make another purchase (Kimberley Burnett, personal communication).

Jack met his second wife, Elizabeth Snowdon in 2002, through his friend Michael Smithson, another model-train enthusiast, who was Elizabeth's brother. Jack, who often had dinner with Michael and his wife, met Elizabeth at such a gathering while she was visiting from New Zealand. They obviously took a shine to each other because when Elizabeth challenged Jack to visit her in New Zealand, he promptly did so, arriving several weeks later. Over the next 12 years, they spent six months a year there, avoiding Canadian winters, and six months of the warm seasons at Jack's home. The latter years, however, were spent at Riverpark Place Retirement Residence, Ottawa.

They married in 2007 under perhaps typical Jack-like circumstances. Jack, being a fun-loving individual, took Elizabeth one morning to the "post office," actually the Ottawa City Hall, where he inquired where one could get married. When Jack was informed that he was at the right place, Elizabeth asked: "Who are you getting married to Jack?" "You, of course" said Jack. So it was on the morning of 15 October 2007 that Jack and Elizabeth Snowdon-Gillett were married and celebrated with a simple wedding breakfast — a cup of soup at Tim Horton's, Jack's favourite coffee shop chain (Elizabeth Snowdon-Gillett, personal. communication).

The passion for travel and exploring that was in Jack's blood had taken him, earlier in his career, beyond North America and Mexico, to such places as Columbia, Costa Rica, Venezuela, Hawaii, and Europe. He now continued his explorations with Elizabeth on a cruise around Australia, tours of New Zealand, and onward to Fiji, Bali, and Samoa. Their attempts at camping in New Zealand resulted in some memorable moments.

Elizabeth suggested they camp while touring New Zealand, but Jack said he was "too old for camping." Nevertheless, they did buy a tent and, with considerable effort and time, managed to erect it on their first try. This occasion became a source of amusement for fellow campers at the site who set up their lawn chairs to watch the unfolding event that resulted in the tent, initially, being erected inside out. Putting their tea cups aside, the onlookers gave them a round of applause. Subsequent camping efforts went more smoothly with a notable exception. While visiting Rotorua, the thermal capital of New Zealand, and not relishing being cold and uncomfortable at night, they pitched their tent in an area where the ground was warmed by a hot underground stream. Unfortunately, their inflated mattress collapsed in the dead of night from the excessive heat build-up under it. They couldn't find a thing in the dark, but got a great laugh out of it (Elizabeth Snowdon-Gillett, personal communication).

Jack died peacefully on Saturday, 27 December 2014 in his 97th year (Figure 4). He is survived by his wife Elizabeth Snowdon-Gillett, daughter Kimberley, son Peter, and granddaughter Shannon. Many fond memories were made and are cherished by Jack's immediate family and by his extended family in New Zealand. Jack's professional contributions to taxonomy and floristics and his amiable assistance to others reflect a life full of achievements. As Kimberley and Peter remarked at his memorial service (5 January 2015), their father was a great adventurer with a true zest for life and an eagerness to experience all that life has to offer.

FIGURE 4. John M. Gillett. Family photo: 31 May 2014.

Acknowledgements

Much of the personal history and anecdotes presented here, which reflect the contributions of Kimberley, Peter, and Elizabeth, are gratefully acknowledged. I am also indebted to local botanists and colleagues of Jack, especially Dan Brunton, Paul Catling, Stephen Darbyshire, and Ted Mosquin, for discussions and contributions related to Jack's activities with the Ottawa Field-Naturalists' Club, the timeline of his research activities, bibliographic compilation of his publications on file at the Central Experimental Farm, Agriculture and Agri-Food Canada, and anecdotes related to fieldwork. Thanks also to the Canadian Museum of Nature, and especially Chantal Dussault, head, archives and library, for providing a scan of Jack's 1974 photo, and to Stephen Haber for photoshop improvements of original black and white images. Comments on an earlier draft by reviewers George Argus, Daniel Brunton, Paul Catling, and Irwin Brodo are also appreciated.

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Received 22 January 2015
Accepted 4 February 2015

Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

ZOOLOGY

Amphibian Biology, Volume 11, Part 4: Status of Conservation and Decline of Amphibians: Eastern Hemisphere: Southern Europe & Turkey

Edited by Harold Heatwole, and John W. Wilkinson. 2014. Pelagic Publishing, PO Box 725, Exeter, UK, EX1 9QU. 158 pages, 69.99 GBP, Paper.

Studies of population declines have increasingly dominated global research effort on amphibians since the first World Congress on Herpetology in 1989. As has been often pointed out, this now legendary meeting bought together specialists from many countries and when they compared their individual observations, they realized that amphibian declines were widespread in occurrence around the world. A search for a common cause examined many possibilities, among them the accelerating habitat alteration by ever-increasing human populations, increased human harvesting for food and the pet trade, effects of introduced species, pollution, parasites, the spread of the chytrid fungus, and the effects of ultraviolet light and global warming.

Volume 11 tackles aspects of regional declines as the latest in a wide-ranging comprehensive series of volumes on amphibian biology. Each of volume's 4 parts, issued separately, is devoted to regional causes of amphibian declines and the conservation measures attempted. Part 4 contains chapters 39 to 53 authored by one to three of the 25 regional researchers concerned with Southern Europe and Turkey, who contributed to chapters on Italy, Malta, Croatia, Slovenia, Serbia, Montenegro, Bosnia, Herzegovina, Macedonia, Albania, Greece, Romania, Hungary, Bulgaria, Turkey, and Cyprus. The cover features a male Bombina floating on the surface of a breeding site in Hungary. Each chapter summarizes, for the included country, amphibian habitat, species present, their population status, and the extent of studies to date. Many have useful tables and graphs. Also included are the existing protection, major threats, monitoring schemes and conservation programmes and action recommendations. Each country account has its own references section, the majority of included titles are in English but contributions in several other languages add to their comprehensiveness. Virtually all references were published in the 1990s and 2000s. An index to species in all accounts concludes the book.

The editors have solid credentials for assembling the many contributions. Their wide contacts are reflected by their positions and experience. Harold Heatwole is an ecologist and herpetologist currently Professor of Biology at North Carolina State University and Adjunct Professor of Zoology at the University of New England. He is Editor-in-Chief of the journal *Integrative and Comparative Biology* and a Fellow of the Explorers Club. John W. Wilkinson is a conservation biologist specializing in monitoring amphibians and reptiles. For eight years he was International Coordinator of the Declining Amphibian Populations Task Force and is currently Science Program Manager for the charity Amphibian and Reptile Conservation.

This collection is a welcome contribution to help balance the dominance of current northern research output from North America. They provide additional and broader context to the perspective of the problem and comparison of the study approaches underway in a different continent. Although the western and eastern northern continents have no amphibian species in common, they share many similar genera and habitats available to them. Not surprisingly the most dominant threats to amphibians are common to both: habitat loss due to human activities, over harvest, and introduced species. Increasingly, the chytrid fungus is being detected, likely spread by human introductions from contaminated areas. Even in relatively lesser developed countries, highway mortality and poaching are also concerns. Present ongoing studies will at least provide a baseline for future measurement of the success, or lack of it, of current conservation measures that are being attempted to assure a sample of the biodiversity of their region survives.

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Field Guide to the Birds of Australia – A photographic guide

By Iain Campbell, Sam Woods, and Nick Leseberg. 2014. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 392 pages, 35.00 USD, Paper.

I often wonder why people write books. It is a huge amount of work with no real promise of reward. The author states he wanted to produce a simplified book for the novice and visitor. This is a laudable objective as too much information can be confusing. (This is why I recommend the original Peterson bird guides for beginners). The author has selected 714 species of resident birds and regularly occurring migrants out of the Australian list of 780. He uses more than 1,100 photographs as illustrations and provides facing-page text and range maps.

The book begins with a description of the various environmental zones. From a Canadian perspective this is most valuable. The Australian climate, geology and flora are so very different from our lush, green Canada. A portion of finding and identifying birds accurately involves recognising habitat. Canadian visitors to Australia are out of their context, so a good introduction to the eco-zones is a good start.

The species accounts are a little more expansive than Simpson and Day, but they give the same identification information. However, Campbell *et al.* give more on habitat and suggest the best locations to find the species (useful for a visitor). Also, I got a better sense of the chance of seeing a bird.

The photographs are high quality "studio" portraits of both males and females. Seabirds and raptors are often shown in flight. The problem is photographs do not always show the key features. This is exemplified by the photos of White-winged Chough (not a real chough or even a crow). While they are good portraits of this uniform black bird they do not show the large flash of white in the wings. Simpson and Day's art work shows this feature clearly and they also insert a vignette chough on the look-alike currawong page. This is true for several species, such as the Red-backed Kingfisher (the red is just visible behind a branch). Similarly photos give little concept of relative size, something that is important for rails, raptors and ducks. It also means the unusual variations in plumage, such as the odd Fairy Tern that does sometimes have a black tip to its bill, is missed.

The authors say they exclude rare vagrants … as they would confuse the vast majority of users. This makes perfect sense for novices and visitors. So I question the inclusion of Paradise Parrot (no records since the 1920s), the Orange-bellied Parrot (population 30 in remote south west Tasmania) and the secretive Night Parrot (a wildlife photographer spent 17,000 hours over 15 years to get the first ever photos). They also include other vagrants like some penguins, so they show some inconsistency in applying their rules.

Having read through this guide I developed a series of questions. Why create a new guide when Simpson and Day's Field Guide to the Birds of Australia is now in its eighth edition in over 25 years with total sales exceeding over half a million copies? Especially as it is one of the most respected field guides in the birding community. Reviewers comments for Simpson and Day's book include … Birds of Australia is an unrivalled companion … top-notch visual presentation, layout, and informational content …and … a wonderful piece of work. This classic guide is very tough, entrenched competition.

The section on habitats has maps of the geological and vegetation zones. I became confused when I saw the map for Mulga. It covered areas that were designated as other habitats such as Spinifex Grassland. So I went to Wikipedia and selected the Mulga Lands from the list of "Mulga" options. Wikipedia says Mulga Lands are in inland New South Wales and Queensland and their map disagrees with Campbell. It does appear that in Australia, Mulga is an alternative name for the wilderness.

Next I checked Spinifex and found it is a genus of grasses found on the coastal sand dunes of Australia and New Zealand. The inland grasses belong to the genus Triodia (commonly known as spinifex). A map in a scientific paper agrees with Campbell's distribution.

So I moved on to Mallee, a type of eucalypt that has multiple stems on an underground tuber. The map in "Plants of the Mallee Shrublands" from the Australian National Botanic Gardens partially agrees with Campbell's map, but the distribution of Malleefowl is in entire agreement.

I found these inconsistencies puzzling, but not distracting. When the author claims "that this guide almost always follows the International Ornithological Congress (actually the International Ornithologists' Union, formerly International Ornithological Committee) taxonomy (IOC World Bird List 3) (Actually now at 4.4) I was surprised. I had already noted the odd position of the frogmouths and nightjars in the book; the ten to twelfth family in the book as they are 77th in IOC's list of 241 extant families. Even more strange was the seventh position of Australasian Gannet and 19th for boobies. The Sulidae – Gannets, Boobies – are together and 32nd. I am all for putting birds of a feather together (the falcons with the hawk, the waterbirds – ducks, grebes, loons etc.) in a field guide, but this order makes no sense. The authors do split the Osprey into two species – the Eastern or Australian Osprey and the Western Osprey.

The guide covers only mainland Australia and Tasmania, but not the offshore territories. The one star bird on my Aussie list, Common Redpoll, is not included because I saw it on Macquarie Island. Technically Macquarie is part of Australia even though it is over 3,800 km away from the mainland.

So I am not sure how I would make out with this guide in the field. I intend to take it on my next trip to Australasia in 2015 and see how it compares to and supplements Simpson and Day's Field Guide to the Birds of Australia.

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Birds of New Guinea: Second Edition

By Thane K. Pratt, and Bruce M. Beehler. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 528 pages, 49.50 USD, Paper.

Almost 30 years ago I reviewed the first edition of this book and I hailed it as "a worthwhile addition to the world's field guides." The original book covered the official list of 708 bird species, plus 17 species that the authors thought should be included. I had a few criticisms – the lack of range maps, a few errors and a relatively high price.

Two of the three original authors have now written a revised edition. This volume covers the geographical entity of New Guinea, the second largest island in the world, located in the southwest Pacific Ocean. The authors avoid using the political terms for the Indonesian provinces of Papua and West Papua (the west half of the island) and the independent state of Papua New Guinea (the eastern end of the island and its associated offshore islands).

New Guinea was once connected to Australia so it has a similar mammal fauna although its flora is more Asian. New Guinea's much higher rainfall than its dry, flat and less fertile neighbour has an immense biodiversity. With one-half percent of the world's land mass it approaches 10 percent of the total species. This is equivalent to the much larger United States or Australia.

The new edition covers 779 bird species, a seven plus percent increase. It has up-to-date, colour coded range maps (for all but the seabirds and rare visitors) and all the illustrations are in colour. Almost all of the first edition plates have been replaced. The old plates, I said, were "professional and essentially accurate." The new artists have researched plumage details to clarify uncertainties and bring their representation current with any new knowledge. A few vagrants are not depicted, along with the ubiquitous Rock Pigeon – mis-named as Dove, but are fully described. The book, despite 30 years of inflation, is about the same price as the first edition.

The text (separate from the plates) is updated and streamlined. The index gives both the text and plate pages. Be warned, the authors use new English names like Beach Kingfisher, Eastern Osprey and Green Oriole, so the old names have only the text page referenced. This is a very minor inconvenience. Each family and sub-family has an introductory box with much useful information that helps a visitor orient their mind. The authors provide the facts you need to find and identify each bird, including the differences with similar species. In particular, they have added details for subspecies, including their range. This is very important as this region is still in need of research and these birds may be split at some time in the future. Clearly, it will be important to keep good notes.

The introduction has been re-organised and updated. It still provides a fascinating overview of the region's natural history, exploration, ecology and helpful hints for visitors. This is such rich region; it is well worth reading for any avid birder and, of course, essential for the prospective visitor.

In conclusion, New Guinea is the place to go to get the best increase to your life list. You need to remember the authors say "highly mountainous, most(ly) … rainforest and (has) logistically difficult conditions." In addition "the Indonesian Government does not encourage foreigners … "

So if you plan to spend the money, to tackle the heat and physical exertion involved in a trip to New Guinea then this excellent book is an essential resource.

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The Carnivore Way: Coexisting with and Conserving North America's Predators

By Cristina Eisenberg. 2014. Island Press, 2000 M Street NW, Suite 650, Washington, DC, USA, 20036. 29.00 USD for e book format, 328 pages, 30.00 USD, Cloth.

What would it be like to live in a world with no predators roaming our landscapes? Would their elimination, which humans have sought with ever greater urgency in recent times, bring about a pastoral, peaceful human civilization? Or in fact is their existence critical to our own, and do we need to be doing more to assure their health and the vitality of the landscapes they need to thrive? These are questions that Cristina Eisenberg takes on in her compelling new book *The Carnivore Way*.

This jacket cover of the hardcover provides an excellent summary of the text: "Cristina Eisenberg argues compellingly for the necessity of top predators in large, undisturbed landscapes, and how a continental-long corridor — a "carnivore way" — provides the room they need to roam and connected landscapes that allow them to disperse. Eisenberg follows the footsteps of six large carnivores — wolves, grizzly bears, lynx, jaguars, wolverines, and cougars — on a 7,500-mile wildlife corridor from Alaska to Mexico along the Rocky Mountains. Backed by robust science, she shows how their well-being is a critical factor in sustaining healthy landscapes and how it is possible for humans and large carnivores to coexist peacefully and even to thrive. Students, resource managers, conservation organizations, and anyone curious about carnivore ecology and management in a changing world will find a thoughtful guide to large carnivore conservation that dispels long-held myths about their ecology and contributions to healthy, resilient landscapes."

Being a carnivore biologist myself, I found that the manuscript will be a valuable literature source when needing to quote a reference on the ecological importance of predators, maintaining intact ecosystems, and/or for having corridors connecting populations of carnivores, or any species for that matter. Eisenberg writes for both the layman as well as the scientist in an understandable and clear fashion. She weaves personal anecdotes along with scientific references to make each section informative and inspirational. Focussing on western North America, the reader is taken from Alaska and the Arctic down to Mexico and the desert. Her personal experiences alone — like seeing a grizzly bear from 12 feet away near her northwest Montana writing cabin (p. 84), watching a pair of wolves chasing a white-tailed deer across her property (p. 113), observing abundant lynx and snowshoe hare sign while back country skiing (p. 173-174), or getting stalked by a cougar (p. 192) — make her the perfect candidate to write this volume. In fact, these wildlife sightings almost seem too perfect given the contents of this manuscript, and that is what makes it a gem! Even the chapter on jaguars (p. 217) connects to her personal past since she was born in northern Mexico (p. 78), the very area where source populations are producing transient jaguars that have colonized the southwestern United States in recent decades.

The book is laid out in two main sections: Wildways and Where the Carnivores Roam. Part 1 (Wildways) focuses on corridor ecology and the ecological role of large predators and gives the reader a solid understanding on the science behind protecting large areas, connecting them, and the important role that carnivores play in intact ecosystems. That section concludes (chapter 3) with the legal framework, i.e., international environmental laws that apply to large carnivores in North America. This chapter is important in knowing what laws could be strengthened (or maybe even created) to better protect wild carnivores, especially considering that they often make enormous movements, crossing political boundaries and a variety of jurisdictions and land ownership regimes in the process. In Part 2 (Where the Carnivores Roam), Eisenberg examines each of the six large predator species separately and in-depth providing excellent natural history accounts and references on each animal. These chapters (4–9) are important because they describe how individuals use the countryside, which gives the reader a solid understanding of how these creatures survive in both protected places (e.g., wilderness areas, national parks) as well as progressively urbanized locales. The focus on individuals is becoming increasingly recognized in wildlife conservation, rather than just populations, so I appreciated these highly personal accounts including of the Lamar Canyon wolf pack of Yellowstone National Park (p. 139–141) whom I have spent many hours observing and share pictures of in my book *My Yellowstone Experience*.

Many topics are woven throughout these two parts and nine chapters, including carnivore dispersal and movement distances, human hunting and trapping, human use of the area (e.g., ranching, recreation), boundary issues with other jurisdictions including the US-Mexico border fence, ecological importance of predators, and how laws protect (or don't) carnivores in this vast area. In the last chapter (10), Earth Household, Eisenberg nicely summarizes the book. Given that the information provided has a wide reach, and covers many themes, that was not an easy task. In Part 1, she discussed an ecological effective carnivore population as one that is capable of stimulating top-down trophic cascades and, using tenets of the precautionary approach, creating more-resilient ecosystems means conserving large predators. Those chapters lay a framework suggesting that carnivores create healthier environments through both direct acts of predation as well as indirect effects ("the ecology of fear") even if recent scientific papers debate as to the actual effects that they have (e.g., see Biological Conservation, 2012, 150: 143–149). The final chapter does a great job of summarizing and revisiting those concepts as well as taking in knowledge of what the reader learned about the six large carnivore species from Part 2. Eisenberg argues that landscapes that contain large predators will be more resistant to climate change because they create biodiverse, healthy ecosystems (p. 241). The author also stressed that coexistence is a vibrant thread that runs through all the lessons about connectivity, food web relationships, and environmental law (p. 243). She notes that we need to utilize collaboration and ethics to fully realize coexistence with large carnivores (p. 244). There she revisits Aldo Leopold and his seminal land-ethic statements and also discusses how science has caught up to Leopold's 60+ year old quotes to show just how important keeping all of Mother Nature's parts are, particularly predators. The question now is if setting proper policy by politicians and wildlife managers will also catch up to properly conserve these charismatic mammals. In that regard, Eisenberg eloquently describes the need to revisit and rethink the North American Model of Wildlife Conservation where hunting dominates wildlife conservation. She (p. 248) notes that "the model focuses solely on conserving wildlife for hunting purposes. Yet in the United States, only 6 percent of citizens hunt. I'm part of that 6 percent. But in a democracy, basing wildlife management on a hunting paradigm that doesn't address the needs or desires of the non-hunting public (the vast majority of Americans) is wrong if, as the North American Model states, all wildlife is owned by all citizens jointly."

In light of what we know about trophic cascades, recovering the wolf, removing Endangered Species Act protections, and then hunting them down to a bare legal minimum is not only wrong scientifically, but also ethically (p. 248). Eisenberg advocates for a contemporary land ethic that wouldn't preclude human hunting but redefines hunting as a practice in which we don't treat animals like a crop to be harvested and one in which we exercise more restraint and respect for the living beings that we hunt (p. 249). Like many ecologists, she believes that hunting carnivores should be greatly curtailed or even eliminated as her last personal experience in the book attests to when she visits the Great Bear Rainforest in coastal British Columbia and has memorable up-close sightings of grizzly and black bears, populations that have never seen the barrel of a gun. Eisenberg concludes (p. 256) with the thought that we ought to base our relationships with predators on respect, rather than fear, and that it is important to remember that coexistence means different things to different people (from managing carnivores at biological and legal minimum levels to not disturbing them at all). She concludes (p. 256) that "we're all threads in the same cloth of creation, and we dwell in this Earth household together." Clearly the author (like myself) views coexistence on the latter side of the spectrum, i.e., of conserving and restoring populations of carnivores to their natural population densities in as many places as is feasible.

I have but two minor issues with the book. One, the use of scientific names is used throughout each chapter. For the life of me, I don't understand why there is no table at the beginning or end of the document that states these names once and then is not used again so there aren't so many uses of "gray wolf (*Canis lupus*)" for instance. The other problem is similarly trivial and that has to do with the endnotes. There is an impressive 29 pages of notes at the end of the book. However, there are a few places where the endnote doesn't fit the reference, especially in chapter 1 where reference 18 should be for 19 (p. 22) and every reference thereafter is one lower than it is supposed to be finishing with reference 39 which should be #40 (p. 35). But this is nitpicking and it takes a detailed read to even notice these errors.

With that being said, I highly recommend *The Carnivore Way* as it is a great book for the novice and seasoned conservationist alike and should be widely read, particularly by politicians in charge of creating laws to protect wildlife. It is easy to read and engaging, and is a great reference on the importance of maintaining ecologically effective populations of predators. There is even a nice glossary that summarizes the technical terms used throughout the text. Western North America, with its vast public lands, is ripe for carnivore re-wilding and managers, students, and the general public can get an appreciation of this process and of the animals themselves by reading this tome and its associated ~40 black and white pictures and illustrations, including my favourite of 4 cougars using an underpass to travel beneath a 4-lane highway in Canada (p. 31). But these mammals needn't be restricted to just the Rockies (i.e., "the carnivore way") and historically they were not. In time, I hope that a second volume of *The Carnivore Way* will be written by Eisenberg that describes how these sentient beings got better protection (e.g., thru a National Carnivore Conservation Act [see http://www.easterncoyoteresearch.com/worlds-first-carnivore-conservation-act/] – yes, I may dream!) to allow them to re-colonize that large area. I also dream that a future Volume 2 will discuss actions taken toward carnivore conservation and recovery in eastern North America where many of those same species (wolves and cougars most notably) formerly were widespread. If we have recovered white-tailed deer, moose, wild turkeys, beavers, fishers, and even elk to many areas of the East, why can't we also recover the large predators that create such awe, allure, and respect from so many of us? After all, they are as American as any human being is!

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The Sea Among Us: the Amazing Strait of Georgia

Edited by Richard Beamish, and Gordon McFarlane. 2014. Harbour Publishing Co. Ltd., 4437 Rondeview Rd, Madeira Park, BC, Canada, V0N 2H0. 384 pages, 39.95 CAD, Cloth.

The Strait of Georgia (hereafter the Strait) is an inland sea lying between Vancouver Island and mainland British Columbia, extending from Quadra and Cortes islands in the north to the Gulf and San Juan islands in the south. The over two million people that inhabit the shores of the Strait, the majority of whom live in the metropolis of Vancouver, bathe in the "myth of easy living," perpetuated by a mild climate and abundant natural resources. The estimates of marine biodiversity include over 3000 species of invertebrates, 223 fish species, over 350 species of plants, and 11 species of mammals. Then add several dozen species of birds that inhabit the interface between the marine and terrestrial environments. A rich place indeed.

The Sea Among Us is an excellent resource for understanding this amazing area. I would describe it as an "accessible" introductory textbook – full of facts, maps, figures, and photos, but unencumbered by citations at the end of each statement. Rather, there are Chapter Notes at the end of the book, with suggestions for further reading, including some online resources. Indeed, Douglas Bertram (author of the chapter "The Coastal Birds") lamented that "it was tough to write this chapter without formal citations of the vital research and observations" of others. There are 12 authors (including the editors), each a specialist in her or his field, and their lists of acknowledgements are evidence of wide consultation with colleagues.

Roughly the first three-quarters of the book (seven chapters) lays the scientific foundation for the functioning of the marine ecosystem, followed by three chapters on "The People and Industry." I found the numerous excellent diagrams and different styles of maps particularly helpful in understanding the geological and physical properties of the Strait. The pages on tides, tidal currents, tidal mixing, and the influence of estuarine circulation and wind, were the best I've read, and should be studied by anyone venturing onto or into the waters of the Strait. The following chapters then work up the food chain, from phytoplankton, to zooplankton, to larger invertebrates and marine plants, then fishes, marine mammals, coastal birds and finally, humans.

At 80 pages "The Fishes" is the longest chapter, but also sets the stage for the last chapter on human exploitation of this critical resource. It starts with brief life histories of the jawless, jawed and cartilaginous, and bony fishes. The bulk of the chapter describes the use of five habitats by adult bony fish: tide pools and intertidal areas, estuaries and nearshore habitats, mud and sand bottom at intermediate depths, pelagic areas from the surface to 75 m deep and pelagic areas deeper than 75 m. This includes numerous species lists, augmented by photos and sketches, as well as tables of abundance in different geographical areas. The author recognizes that these divisions are somewhat arbitrary, but they serve as useful distinctions.

Seals, sea lions, porpoises, dolphins (including the iconic killer whale, or orca, which is the world's largest dolphin) and baleen whales are all described in the chapter on "Marine Mammals." Causes of historic declines are discussed, as are current and emerging threats, such as human disturbance, including engine noise, and terrestrial pathogens and contaminants entering the marine environment. "The Coastal Birds" chapter highlights many migratory species that depend on the various habitats found throughout the Strait, which provide a wide range of food sources. The movements of individuals of different species, determined by radio telemetry or band recovery, are mapped and highlight the importance of the Strait as a wintering area. One of the most important food sources is herring eggs – when herring spawn in March nearly all the waterbirds in the Strait travel to those sites to feed. In the late 1990s I had the good fortune to witness such aggregations at Hornby Island. There were birds, such as harlequin ducks (we estimated about 4000 during one scan of the shoreline), feeding on the eggs, while others, such as loons and eagles, were feeding on the adult herring. The banquet also drew in seals, sea lions and orcas, all in a loud cacophonous frenzy.

The current and potential impacts of climate change, predominantly predicted changes in water temperature and sea level, are discussed in many of these chapters. Resulting changes in circulation patterns are expected to alter the timing and location of plankton blooms, which will in turn alter the abundance and distribution of invertebrates and fish, and therefore the predators that feed upon them. There is concern that ecological adaptation will have a hard time to keep up to the rapid changes.

Chapters 8 and 9 provide a short history of "The Pre-Contact Era" and "The Zone of Encounter," respectively. The term "Coast Salish" refers to the linguistically and culturally related First Nations that inhabit the entire Strait area and beyond. (It is now routine to refer to the Strait of Georgia, Puget Sound, and Haro, Rosario and Juan de Fuca straits, collectively, as the Salish Sea.) Prior to contact with Europeans, it was a densely populated, complex society with an elaborate and thriving maritime economy. The people used clam gardens, numerous types of weirs, fish traps, dip nets and reef nets, and hunted whales in an annual cycle of activities timed by seasonal changes in the ecosystem. That all changed after European contact. While the date of first contact is still controversial, there is no doubt that the search for a quicker way of moving trade goods between Europe and China/India was behind the 18th century explorations that led Spanish and English explorers to the

Strait. This led to the 1780s smallpox catastrophe, which decimated the Coast Salish. The subsequent non-native settlement of the lands surrounding the Strait was actually a "re-settlement" of lands emptied by waves of disease. It is mostly a story of industrial exploitation of natural resources (trees, minerals, and fish), marine transportation, and more recently, recreational activities. Chapter 10 focuses on the history of industrial fishing, which is really a history of our ignorance of the "limits to resiliency" of the various species and their ecosystems.

In the "Afterword," each author gives their view of the future of the Strait. Despite the litany of abuses in the previous chapters, they share a basic hope for the continued existence of a diverse and resilient Strait ecosystem, inhabited by people who are willing to collaborate and compromise to achieve that goal.

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Marine Community Ecology and Conservation

Edited by M.D. Bertness, J.F. Bruno, R.R. Silliman, and J.J. Stachowicz. 2014. Sinauer Associates Inc., 23 Plumtree Road, P.O. Box 407, Sunderland, MA, USA, 01375-0407. 566 pages, 116.68 USD, Cloth.

This book introduces itself as a sequel to the 2001 edition by M.D. Bertness the principal editor. Research in marine ecology has progressed and the summary of information available is more comprehensive with new data and more global research included. Like the 2001 edition this is a textbook for graduate students and ecologists, particularly those preparing for comprehensive exams. The earlier edition was also out of print.

As a text which summarizes all of the research to date and the situations in the current oceans of the world, the book is understandably quite dense. It begins with the early studies in marine ecology and the ecologists which made those studies. Where do we start (?) is a question which might puzzle the reader when faced with such a large topic and wealth of data. The book is organized into 23 chapters, summarizing the work of scientists on abiotic and biotic forces in the different salt water environments in the world. The book is subdivided into sections Processes that Generate Patterns in Marine Communities, Community Types, and Conservation following a history of Marine Community Ecology. Then each has topics related specifically to communities, populations, diversity, predator-prey relationships and diseases. But the mirror of discussion as in all of ecology is regrettably pollution, climate change, threats from various sources and the usual doom and gloom record of decades, even centuries of pollution and lack of any management strategies. At the end of the text are a few words of hope, strategies for restoration and some reports of current ecosystem conservation and management.

Most ecological research is scientific study in response to an obvious threat in the ecosystem or a more comprehensive study in response to the history of pollution and mismanagement in any one area of the seacoast. The current focal points of research seem to be marine protected areas and marine spatial planning and it is to this end that the book leads us. Overfishing, intensive harvests of shallow water invertebrates, and habitat loss are factors which have been well documented in oceans at this time and the effects of these changes over the past half-century, since records have been kept, show a decline in biomass harvested and the top-down and bottom-up effects on different ecosystems' production. The accumulation of pollutants near cities and from any given landmass is a topic which is only in the beginning stages of documentation but impacts many of the inshore marine ecosystems and species diversity. The book highlights warning signs and documents red flags from many different areas over long periods of time. The time-line is important since pollution did not start with the modern generation and certainly will not end in the present day.

There is a wide variety of literature produced concerning Marine Communities but the oceans are vast and the areas which have been studied are only a sampling of the multitude of habitats in any ocean type. For example, to study the biogeography of ocean communities, one has to study latitude and the abundance of species which are represented from warm to cold latitudes, the regional variations due to currents, and environmental heterogeneity of specialized areas. With latitude variation there have to be studies of different community types in intertidal, soft sediments, salt marshes, coral reefs and pelagic environments to name a few. When working with each of those communities the factors of climate change, threats of overfishing and habitat degradation have to be balanced to discover the original abundance and interaction with all species represented. Some consideration has to be given to restoration of endangered species and marine conservation of water quality, species interaction, native versus introduced species and nearby land developments before a reasonable prediction of future community structure can be suggested.

That the book is dense and technical is understood by its definition. This level of research has to be available to all researchers and professionals who study the complexities of any ecological problem regarding the world's oceans and their contact with continents. The only chapter which would be regarded as entertaining leisure reading was the first, A Short History of Marine

Community Ecology and perhaps some of the last chapter when the editor relates accounts of media attempts at changing our food habits in the interest of conservation. A suggestion of further study opportunities is also a positive informal note within the technical material. This is a go-to book for answers of what has been studied so far and a check-list of the people involved in the studies. I worked my way slowly through the book and learned a lot of marine ecology in the process even though I pride myself in staying current with news and features involving general ecology topics. This text is a monumental work and we are better informed having it in hand.

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Marmot Biology – Sociality, Individual Fitness, and Population Dynamics

By Kenneth B. Armitage. 2014. Cambridge University Press, University Printing House, Shaftesbury Road, Cambridge, UK, CB2 8BS. 407 pages, 66.20 CAD, Cloth.

This is a solid book. The author has spent nearly half a century studying the Yellow-bellied Marmot (*Marmota flaviventris*) which certainly gives him the foundation to write such a work. This book is a massive synthesis of marmot biology; there are almost 800 references …another indication of the thoroughness of this book. There are some nice pictures, and some interesting lore in the first chapter, but largely, this is not meant to be a coffee table book but is going to appeal to ecologists, ethologists and hard core marmot enthusiasts.

Although there are 13 (according to table 1.2) or 14 (according to Figure 2.3) other extant marmots (including the widespread groundhog/woodchuck *M. monax*), the book's coverage is dominated by the author's own focus animal. One entire section (of six in the book) is exclusive to the Yellow-bellied, with the other sections heavy with it. I think that another section in the book, with chapters focussed on the other species, would have balanced the book. However, the information presented on the other marmots is enough to justify titling the book as it is.

The ecology of marmots is largely the concern of the book, and the coverage here is both in depth and thorough. However, the section on predators barely occupied three pages of text, and parasites were given similar short shrift. It is unclear whether this represents a dearth in the literature, or the author's purposeful exclusion. However, the other fields, whether habitat use, play behaviour or alarm calls, were well-developed.

The long-term, continuous nature of the Armitage's study, the second longest for any mammal, allows for multi generational analyses of his colonies. Breeding success, kinship, and more can best be studied by long term determination of a researcher. We read about the marmots which leave their natal colony, which stay and why this is beneficial. We also learn about home range changes, over wintering physiology and burrow usage.

Technically, data were largely well presented. A few of the graphs had too much information and could have benefited from splitting the multiple curves among two sets of axes. There were several tables which I found odd…normally columns in a table represent the variable(s) being measured, and the numerical data for one or more parameters. Instead, these odd tables had only text, sometimes as abbreviated sentences which may have been summaries of field notes. It is unclear why these passages were not just incorporated into the text.

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An Indomitable Beast: The Remarkable Journey of the Jaguar

By Alan Rabinowitz. 2014. Island Press, 2000 M Street, Suite 650, Washington DC, USA, 20036. 241 pages, 30.00 USD, Cloth.

The iconic jaguar is surprisingly one of the least known of the big cats that also includes tigers and lions. The largest spotted cat is more secretive and leery of humans, which has probably also contributed to the jaguar's relatively better conservation status. The author has traveled around the world to research and save not only many different species of endangered felids, but also their habitats. In this book, he gives a personal journey beginning in childhood and developing into a professional career spanning over 30 years that has primarily revolved around the jaguar, which is aptly referred to as the indomitable beast and the reluctant warrior.

At the age of 5 years, Rabinowitz developed a mysterious fascination with the jaguar when his father regularly took him to the Bronx Zoo in his hometown of New York. Gravitating to the sciences in college and feeling more at home in the outdoors led him to complete an MSc on the biology of the endangered gray bat and a PhD on raccoon ecology in Tennessee. Then a serendipitous meeting with the legendary conservation biologist George Schaller brought Rabinowitz full circle back to his animal of first love. He jumped at the chance of conducting research on the poorly known jaguar in equally unknown Belize.

Afterwards, a two-decade hiatus took Rabinowitz to Asia and the study of other species in need of conservation, but the largest cat in the Americas was always back of mind. It wasn't until 1999 that he got back into jaguars when he organized a meeting on the current state of research and conservation of this species. This book, his second on jaguars, begins here when he sees the revelation of genetic data coalescing with corridors of fragmented forested habitats that gives a better understanding of how the indomitable beast can survive in the face of humanity.

But the story actually starts further back in the Pleistocene ice ages about 2 million years ago when now extinct species and/or subspecies lived in Europe and the Americas. However, only the tropical jaguar survives today with a range from the southern United States to northern Argentina. The big cats, including jaguar, are thought to have their origins in Asia and the likely route of New World colonization was across the Bering Strait land connection in the northern hemisphere. The corridors in these colder, harsher climates were the precursors to the present-day fragmented landscapes that the jaguars now need to navigate and that governments need to preserve.

After the jaguar became established in the Americas and the Eurasian jaguar went extinct, modern man crossed the same land bridge into the New World as early as perhaps 40,000 years ago. With the gradual change from hunter-gatherers to farmers, humans began to have a profound influence on the distribution of jaguars by altering the natural habitat. Early civilizations such as the Olmecs in 1,500 BC Mexico further modified the landscape but also established a cultural and spiritual link with the jaguar, a mystique that still exists to some extent today.

Paradoxically, the European colonization of the New World in the 15th century was devastating to the indigenous pre-Columbian civilizations but enabled the jaguar to re-establish itself in a reforestation of previously modified landscapes. However, by the 19th century population growth and development were slowly reclaiming again the forested jaguar habitats. The double-edged sword of overhunting of jaguars for the fashion industry and hunting its prey species such as deer and peccaries for human consumption further endangered the chances of survival. This prompted the Convention on International Trade in Endangered Species (CITES) and the US Endangered Species Act to protect the jaguar and its habitat beginning in the 1970's.

Rabinowitz does a stellar job in weaving the complex and compelling stories of the jaguar by telling them through the lens of evolutionary and cultural history. This starts from day one in the Bronx Zoo during his childhood to the Cockscomb of Belize in his earlier groundbreaking research and the recent drive to ensure its survival through the Jaguar Corridor Initiative that preserves the connections between fragment habitats in the New World tropics. He tells this life-long journey through his association with the Wildlife Conservation Society and now the charitable organization Panthera. This is an inspirational read for not only professional biologists but also amateur naturalists with an interest in the passion of science and environmental conservation.

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BOTANY

Flora of Virginia

By Alan S. Weakley, J. Christopher Ludwig, and John Townsend. 2012. Botanical Institute of Texas Press,1700 University Drive, Fort Worth, TX, USA, 76107-3400. 1572 pages, 89.99 USD, Cloth.

If a Canadian botanist were looking for just one volume to provide a clear window into much the flora of the eastern United States, this would be it. This opinion offers no disrespect to the floristic treatments from some border states (e.g. Voss and Reznicek's remarkable 2012 *Field Manual of Michigan Flora*) but those must-have volumes are from the neighbourhood, as it were. The *Flora of Virginia* covers the more distant geographic heartland of the eastern United States. In doing so it treats some 3,200 (2,500 native) taxa and provides insight into the biodiversity of one of North America's floristic hot spots. Amongst the treatments of many familiar species, the Canadian botanist will find the discussions of seemingly exotic southern taxa to be both fascinating and helpful.

This flora is the product of careful and thorough scholarship by many of the state's top field botanists and builds upon some 300 years of previous investigations. Moments in the historical progression leading to this publication are colourfully described as constituting "fire, piracy, plague, penury [and] plagiarism" (page 21). Hopefully not for the current team! The end product is a superb marriage of field-based skills, herbarium investigations and the review of mountains of scientific analysis.

Flora of Virginia is really two books in one. The first 'book' is the 85 page introductory section that provides a comprehensive biophysical and historical foundation for the study, explaining the complex geological nature and landform history of Virginia. This introductory section is comprehensive, well illustrated and provides insights into the distributional and even taxonomic interpretation of particular species and species groups. The review of the history of botanical exploration in Virginia is presumably intended primarily for local readership. It is also of interest to Canadian readers, however, for its examination of the contributions of investigators who were active in parts of eastern Canada. Through his onsite work between 1933 and 1947, for example, the brilliant field investigator and taxonomist Merritt Fernald arguably did more than any other botanist to put the floristic richness of Virginia on the continental map. His rambling but remarkably informative and most entertaining reports on those botanical travelogues in *Rhodora* will be familiar to and appreciated by those who have also studied his similar, earlier explorations of Newfoundland and the Maritimes. Accordingly, the statement that "*unsurprisingly, Fernald didn't endear himself to many Virginians*" (page 16) is surprising and strikes me as a bit harsh. Having had the pleasure of reading his at times over the top travelogues to help me retrace some of his forays through eastern Virginia, I have the sense that he enjoyed and respected both the region's landscape and its people.

The second 'book', as it were, is composed of the taxonomic treatments. This forms the heart and soul of the flora. Its heart is the keys, its soul the technical descriptions. Both are based on insights developed from decades of first-hand field experience.

A flora lives or dies on the quality of its keys. The keys in *Flora of Virginia* provide an excellent a balance between technical precision and practical application. Few couplets are so over-simplified as to be substantially indiscriminate or are so complex as to drown the user in words and numbers. Unnecessarily technical language slips in now and then, like 'suffrutescent' in a number of key couplets where simpler language ("somewhat shrubby") would have been clearer and just as accurate. But these are exceptions to the dominant employment of clear and practical language.

The technical descriptions use measurements and morphological characteristics derived from the original examinations of large series of Virginia specimens. The concise descriptions of site ecology and distribution within and beyond the state work well too. Taxonomic interpretations throughout the flora seem to give great weight to the conclusions of genetic studies, resulting in the application of many names which will be new and/or unfamiliar to some readers. While they may find the proliferation of new names to be hasty or at least unsettling, thorough representation of the regional synonymy is also provided. Accordingly, more traditional and/or morphologically based taxonomic interpretations are also available.

The technical descriptions benefit from excellent black and white line drawings, leaving colour images to be applied to best effect for habitat illustrations and selective maps. It is good to see *Flora of Virginia* resist the temptation to include a 'pretty wildflowers' section, which seems to be frequently considered a necessary marketing component in a technical flora. The botanical utility of such a section is questionable and is only achieved with additional production cost and thus a higher purchase price. I especially appreciated the presentation of comparative arrays of black and white line drawings for important identification characteristics such as the leaf shapes of *Carya* (page 652) and *Quercus* (pages 612-613), the perigynia of several tricky *Carex* Sections (*Laxiflorae*, page 1022 and *Ovales*, page 1025) and so on.

Fully 1,000 of the native species included in *Flora of Virginia* are characteristic of or endemic to the southeastern United States. For Canadian botanists discussions of these provide new insights into genera and species groups that occur in Canada or are candidates to do so.

A few glitches and errors were noted, as is inevitable in a production of this scale and intricacy, but they are mostly minor. *Isoetes mattaponica* (page 67), for example, is not the only Virginia diploid of this genus (there are several diploid *Isoetes* in the state). A trivial typo is evident in the *Lycopus* key ("ta-pered" in the *L. uniflorus* couplet (page 667) is presumably meant to be 'tapered'). In the first printing of the Flora there was a significant error (omitted text) in the treatment of *Vicia* (page 603), but this was corrected with an Erratum page for second printing copies. Also, Melanthiaceae (page 1162) is missed in the otherwise very helpful Family Index printed on the inside back cover. And I am getting really picky here, but I don't see why the historical photograph on page 15 couldn't have been straightened so the field botanists depicted don't all seem to be leaning. Notwithstanding these small annoyances, this million word volume seems remarkably free of such problems.

The *Flora of Virginia* is well bound and has clear, readable type. The font size is perhaps somewhat small for readers with eyes as old as mine, but any larger font would expand the heft of this already mighty tome to an unmanageable degree. Though too unwieldy to be readily carried into the field, the book is certainly durable and portable enough to serve as a valuable vehicle-based reference tool.

The *Flora of Virginia* is an eye-opener and a delight. It belongs in the library of every eastern North American field botanist. While it would be a stretch to say it was worth the wait between the production of the first flora of this region and this tome (275 years!), it is a fine achievement and will become an instant classic. For decades to come it will be a valuable tool for field botany, conservation initiatives and a wide spectrum of academic applications in eastern North America.

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OTHER

Ian McTaggart-Cowan: The legacy of a pioneering biologist, educator and conservationist

By Ronald D. Jakimchuk, R. Wayne Campbell, and Dennis A. Demarchi. 2014. Harbour Publishing, Box 219, Madeira Park, BC, Canada, V0N 2H0 and Biodiversity Centre for Wildlife Studies, 3825 Cadboro Bay Road, PO Box 55053, Victoria, BC, Canada, V8N 6I8. 404 pages, 49.95 CAD, Cloth.

The introduction by first author Ronald D. Jakimchuk correctly states that this volume is "a unique and special tribute to the life and accomplishments of Dr. Ian McTaggart-Cowan. And what a life it has been! Well-lived, productive, innovative, influential, pioneering, seminal are all words that come to mind. However, even in combination these words seem inadequate."

Ian's parents, Garry McTaggart Cowan and Laura Alice Mackenzie, were married in 1909 in Edinburgh, Scotland. Ian was born there the next year. Garry, his father, was offered a managerial position at a mine quarrying limestone on Texada Island in the Strait of Georgia so the family moved to Vancouver in 1913.

In 1923, National Parks of Canada offered a book prize to any Boy Scout who achieved his naturalist badge and submitted a bird diary covering a year of observations, for which Ian, one of the winners, received a copy of Gordon Hewitt's book, *The Conservation of the Wildlife of Canada.* Ian's diary was read by J.A. Munro, chief federal wildlife officer for Western Canada. Munro pointed out mistaken bird identifications that were based on his single book, Reed's bird guide. In his final year of high school, Ian attended a lecture about small mammals by Kenneth Racey at the Burrard Field Naturalists' Club. From that moment, Racey became Ian's mentor; he accompanied the Racey family on many field trips and to their summer cottage.

In 1927 Ian, now six feet, four inches tall, enrolled in the honours zoology program at the University of British Columbia (UBC). He obtained important summer jobs as a naturalist, beginning in 1930, and graduated with his honours degree in biology in 1932. He went immediately to Berkeley, California to study under Dr Joseph Grinnell of the University of California, obtaining his Ph D degree in 1935. From then until 1940 Ian was on the staff of the British Columbia Provincial Museum, from which he made a number of collecting trips to fill in gaps of knowledge. In April 1936 he married Kenneth Racey's daughter, Joyce.

In July 1940 Ian became an assistant professor of zoology at UBC, followed by promotions to a full professor in 1945 and head of the department in 1953. He had one notable peculiarity: whenever someone began speaking in a lecture theatre he closed his eyes and appeared to be sleeping. "Yet as soon as the speaker ceased, he would be able to summarize everything that had been said or ask questions that demonstrated his complete grasp of the lecture's content."

Ian was a pioneer in using television to educate the public. His first series, *Fur and Feathers,* began in 1955, followed by *The Living Sea* and then *The Web of Life.*

His excellence in teaching, his numerous scientific publications in all branches of zoology, and his public outreach together caused him to become known across Canada. He was appointed as a Fellow of the Royal Society of Canada at the unusually early age of 36. His UBC role expanded to become Dean of Graduate Studies from 1964 until his "retirement" in 1975.

As a mammologist Ian named 17 new subspecies of mammal, 15 of which were from British Columbia. Charles Guiguet named a subspecies of vole, *Microtus townsendii cowani* in his honour. Among invertebrates, a chiton in the family *Ischnochitonidae* was named *Tripoplax cowani* and an amphipod in the family Hyalidae was named *Parallorchestes cowani.*

Ian's wife, Joyce, had been his field partner at the start of their marriage but she quickly morphed into conjoint positions as supporter, skilled adjunct, assistant, and social convenor. When a cougar was deposited at their back door, Joyce had taken all its measurements and sexed it before Ian arrived home to deposit it in the University freezer. Joyce prepared refreshments for "cheerful gatherings at the Cowan household in Point Grey" and took containers of hot soup to Stephen R. Johnson when he conducted all-night experiments in the old UBC vivarium. Ian and Joyce celebrated their 50th wedding anniversary in April 1986. Her health declined in the late 1990s but she was able to stand in a reception line that honoured Ian at Government House in 2000, perhaps her final formal public appearance. She died peacefully at home on February 29, 2001, after 66 years of marriage. She was predeceased by their son Garry 15 January 1997 at age 56, and survived by Garry's daughter Mariana and son Robert and their daughter Ann Schau.

Ian earned a reputation as a scientist and conservationist but his role was that of a statesman rather than of an activist demanding change and action. His speech, "Wild values for the future" to the annual convention of the BC Wildlife Federation in May 1969, reproduced in its 12-page entirety in this book, offers an ideal understanding of his ethos.

In 1972, Ian invited Wayne Campbell to his home to join with him in planning what became the magnificent, fact-filled, beautifully illustrated four volumes, *The Birds of British Columbia.* The first two volumes were published in 1990, with four additional authors listed; information was contributed by biologists and amateurs throughout the province.

Ian retired from UBC in 1975 and moved to Saanich on Vancouver Island in 1976. The next year, UBC awarded him the title and degree of Doctor of Science *honoris causa*. In 1979 at the age of 69, he was appointed Chancellor of the University of Victoria for a five-year term, chairing convocation, conferring degrees and serving on the board of governors and the senate.

Ian at this time learned computer skills, to participate more intensively in Volume 3 of *Birds of British Columbia* (with a seventh author, John Smith) in 1997 and volume 4 in 2001 (with Andrew Stewart as the substitute seventh author). By volume 4, Ian was 91 and in his twenty-sixth year of retirement.

Among his many honours I would single out the Aldo Leopold Award and Officer of the Order of Canada, both in 1970, the latter in only the third year of this award! He was named Officer of the Order of British Columbia (OBC) in 1991.

When awarded the Doris Huestis Speirs Award in 1998, the highest honour of the Society of Canadian Ornithologists, his acceptance speech demonstrated the problems in bird management that are unique to British Columbia. He noted, "The objective of most conservation measures seems to be to stop the clock; this we cannot do."

In his retirement years Ian was active in his other hobbies: gardening, growing prize rhododendrons, and philately, winning gold medals for Law Stamps and Federal Revenue Stamps.

"Ian had a very strong aesthetic response to the natural world. He lived a charmed life, being able to experience so much pristine or near pristine wilderness areas and habitats rich in wildlife, and his concern for such areas carried through in his efforts to preserve them and their values… He was a lifelong supporter of the Royal British Columbia Museum. He enjoyed symphonic and choral music and was a supporter of the Sydney Classical Orchestra where he attended concerts even into his 98th year. He was a shining example of good citizenship, having spent his entire life as a learner and educator. Ian contracted pneumonia and died April 18, 2010, just over two months short of his 100th birthday. He had remained active, attending Finnerty Gardens only a week before his death.

Ian was awarded a Doctorate of Environmental Studies by the University of Waterloo (1976), an honourary D.Sc. degree by the University of Victoria (1985) and the University of Northern British Columbia (1997), and LL.D. degrees by the University of Alberta (1971) and Simon Fraser University (1981). In 1988, the Association of Professional Biologists of British Columbia established the Ian McTaggart-Cowan Award of Excellence in Biology. His name is also associated with three permanent post-secondary scholarships to assist students: the Ian and Joyce McTaggart-Cowan scholarship and the Dr. Ian McTaggart-Cowan Scholarship in Environmental Studies at the University of Victoria and the Ian McTaggart-Cowan scholarship in Wildlife Management at the University of Northern British Columbia. In addition, the University of Northern British Columbia created the Ian McTaggart-Cowan Muskwa-Kechika Research Chair and the University of Victoria, the Ian McTaggart-Cowan Professorship of Biodiversity Conservation and Ecological Restoration in its School of Environmental Studies. The University of Victoria named a student residence at its Commonwealth Village in his honour. An invertebrate, a septibranch bivalve, *Cuspidiaria cowani* and a mammal, *Microtus townsendi cowani,* were named in his honour.

The longest Chapter (8) in this book is 148 pages. It correctly identifies Ian as the leading teacher of wildlife management in Canada. Ninety biologists, nine of them women, submitted their memories.

Jakimchuk, Campbell and Demarchi introduce the Memories section by explaining that these people (including nine women: Mary Agnes Bryant, Joyce Lanko Elliott, Pat Johnston, Deb Kennedy, Wini Kessler, Briony Penn, Mary Taylor, Nancy Wilkin, and Robin Wilson), had done their research before the days of GPS, radio-collars, and computers. They had "little more than notebooks, pencils and binoculars." Gore-Tex rain gear, lightweight down outerwear, and motel accommodations were unknown. They thought they had "the best jobs in the world"– and they did. The following are a few selected reminiscences:

"We are not lost. We have not crossed any ocean." "Hindsight is better than foresight by a damn sight." (James F. Bendell). "Passion and enthusiasm will get the job done." (Wayne Campbell). "There are no silly questions when asked honestly." (Valerius Geist).

"I was asked for a professional opinion, not my personal opinion." (David Francis Hatler). Grizzly Bears hunted ground squirrels "like swatting mosquitoes with a sledge hammer." (Lindsay Jones). "Tell me what you want to do and I will find the money." (Charles J. Krebs). "Wildlife management is 95% people management." "I judge a person's interest in their profession by the size of their bookcase." (Peter Ommundsen). "Choose your parents carefully. Find yourself an excellent partner. Eat lots of venison. Maintain enthusiasm." (Rod Silver). "Students would be better served by purchasing a good book rather than a bottle." (Tom Sterling).

Longer memories include the following. On a bet with a 20-minute limit, "Cowan took out his [pocket] knife and proceeded to skin out the ptarmigan in near perfect condition." (Tom J. Cade)." Dr Cowan set the bar high for his graduate students. He expected logical data, sound interpretation and good science. Implicitly he promised his support, his honesty and integrity and always the inferred hope of a lifetime adventure in the fresh air. He showed a deep respect for all living things as a necessary component of life on this planet. … As a West Coast protégé of Aldo Leopold, he was an authentic icon who taught his personal values of self-reliance, high ideals and the need for evidence-based knowledge." (Alexander Dzubin).

"After leaving UBC … I learned that about two-thirds of the scientists then in CWS had earned their first degrees, and then their masters, at UBC after Dr Cowan had come." (Tony Erskine). At "Exploding Humanity, the Crisis of Numbers" in 1968, we invited Ian Cowan to speak at the closing session. "It was a carefully reasoned argument that was well received by the audience." (Bruce Falls). "We raced to find a seat in the first year zoology lectures given by Ian McTaggart-Cowan. An overflow squeezed in each week to hear 'his ability to communicate and educate with facts, illustrations and a wealth of knowledge, most of it obtained through his own field explorations'."(Bryan R. Gates).

A great number of his students obtained employment as government biologists. "Many got frustrated and essentially gave up and left, but the ones he worried about most were those that gave up and stayed." (Douglas Heard). "He shared [his] fascinations with an infectious enthusiasm and ready smile." (Ron Jakimchuk). "The word 'spry' best conveys my impression of this extraordinary person, [with] boundless energy, sharpness of mind and keen wit." (Wini Kessler).

"He was incredibly accessible to students, always listened to their ideas and was completely unstinting in his encouragement of anyone who was genuinely interested … the work ethic he modelled was inspirational." (Ian Stirling). "He remained loyal to graduate students – Canada's last enslaved people." (Robert Weeden). Chapter 11 summarizes the main findings of 123 theses and dissertations and also presents "A student's appreciation" by David Hatler.

This compendium is marvellous. It will remind every biologist of "the good old days" of hardship, privation and low remuneration. It should act as a stimulus to every grad student in zoology or wildlife management. How fortunate that Howard White once took a class from Ian McTaggart-Cowan, became the president of Harbour Books, and has made this sumptuous, well-illustrated book his firm's biography of the year!

C. STUART HOUSTON

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Conrad Kain: Letters from a Wandering Mountain Guide, 1906-1933

Edited by Zac Robinson. 2014. University of Alberta Press, Ring House 2, Edmonton, AB, Canada, T6G 2E1. 468 pages, 34.95 CAN, Paper.

Conrad Kain was arguably the pre-eminent mountain guide in Canada in the early years of the 20th century and left a legacy of first ascents and epic climbs in his native Austria, in his adopted home in North America (e.g., Mount Robson), and in New Zealand's Southern Alps. Kain was born in 1883 in Nasswald, Austria and started his guiding career in 1904. Within five years, he had become a much-sought-after guide for challenging climbs in the European Alps. He augmented his meagre guide's fees by back-breaking labour in a rock quarry, supporting his widowed mother and three younger siblings (he continued to send her money until his death). But his desire for a better life, away from the rigid hierarchy of European society, coupled with a burning desire to travel and see the world, led him to emigrate to Canada in 1909, where he worked for many seasons as a climbing guide for the Alpine Club of Canada (ACC). Kain lived out the rest of his years in Canada, with only one short visit back to his homeland in 1912, although it was never far from his thoughts.

After Kain's death in 1934, his client and friend J. Monroe Thorington edited a collection of his journal articles, diaries, and letters, which was published by The American Alpine Club as his autobiography, *Where The Clouds Can Go*. However, it wasn't until 2005 that a treasure-trove surfaced – 144 letters that Kain had written to his dear friend Amelie Malek between 1906 and 1933. It was Malek, whom he had guided with her sister in 1906, who taught Kain to write English by correcting his letters; who virtually served as his literary agent by correcting, translating, typing and forwarding manuscripts to magazines and alpine journals; to whom he sent his diaries with the hope of publishing them, and who shared all with Thorington for his book. Unfortunately, none of Malek's letters to Kain have been found.

In the short Foreword, mountain historian Chic Scott provides a thumbnail sketch of Kain's life and sets his mountaineering accomplishments in context. This is followed by three very useful maps of the European Alps (pre-WWI), the Rocky and Columbia mountains of Canada, and the Southern Alps of New Zealand. Then Robinson discusses the letters themselves in the Introduction: how he found out about them, the relationship between Malek and Kain, and the importance of letters in understanding individuals and in preserving history. The bulk of the book is the letters themselves. Kain's earliest letters to Malek were almost entirely in German (translated and transcribed for this new volume by Maria and John Koch), with short passages in English, but by the end, Kain was writing almost entirely in English and lamenting his loss of fluency in his mother-tongue. Robinson has ordered the letters chronologically and throughout the book has skillfully annotated them to fill in gaps or provide context. The Epilogue, written by Don Bourdon, then head archivist at the Whyte Museum of the Canadian Rockies in Banff, Alberta, where the letters were deposited, tells the compelling journey of the letters between Kain's death in 1934 and their donation to the museum in 2005.

From his letters, it's obvious that Kain loved climbing mountains for the physical challenge, to meet interesting people, to make a living, and for opportunities to travel around the world, but most especially because of his all-consuming love of the natural world. He often lamented that many of his colleagues and clients did not appreciate and understand nature. In winters, he frequently spent months alone in remote areas, trapping fur-bearing animals and meat hunting. He wrote that these were among the happiest times of his life and that "the beauty of nature and the distraction do a lot to brighten one's life and one forgets, even if not totally at least for some time, the sad parts." Kain kept abreast of world affairs by reading newspapers and books, and would get depressed over the situation in war-time Europe and the inequality between rich and poor.

Although a slight man, Kain possessed almost inexhaustible strength (e.g. during the 1924 ACC camp he led four ascents of Mount Robson in little over a week) and courage, was a good hunter, trapper and all-round woodsman, as well as a very competent camp cook. These attributes, plus his desire to travel to new places, landed him work on two Smithsonian Institution scientific expeditions: a joint one with the ACC, to the Mount Robson area of British Columbia in 1911, and the following year to collect fauna in the Altai Mountains of in East-Central Asia (Siberia). Kain also spent three summers working for A. O. Wheeler on the Interprovincial Boundary Survey between Mount Robson and Crowsnest Pass. Knowing that Malek loved wildflowers, Kain wrote about which ones he had seen and frequently sent her dried ones collected on his outings. Kain always regretted that he had not been able to complete high school, and "Had my fate been different, I might have become a scientist."

In her own letter to Thorington in 1935, Malek summed up Kain's letters best: "They are no master pieces of elegant style and learnedness, but they are full of [the] flow and enthusiasm of youth, they show the fire of Con's roving nature and above all, they show his love of nature, and his kind-hearted, grateful and just feeling in everything" (p. 426). As Kain signed off many of his letters ... *Bergheil* – long live the mountains.

Literature Cited

Kain, C. 1935. Where the clouds can go. Edited by J. Monroe Thorington. American Alpine Club Inc., New York, NY, USA.

CYNDI M. SMITH
PO Box 70, Mountain View, AB, Canada, T0K 1N0

NEW TITLES

Prepared by Roy John

† Available for review * Assigned
Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, AUD Australian Dollars.

ZOOLOGY

***Amphibian Biology, Volume 11, Part 4: Status of Conservation and Decline of Amphibians: Eastern Hemisphere: Southern Europe & Turkey.** Edited by Hal Heatwole, and John W. Wilkinson. 2014. Pelagic Publishing, PO Box 725, Exeter, UK, EX1 9QU. 158 pages, 69.99 GBP, Paper.

***Birds of New Guinea: Second Edition.** By Thane K. Pratt, and Bruce M. Beehler. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 528 pages, 49.50 USD, Paper.

***The Sea Among Us – The Strait of Georgia.** Edited by Richard Beamish, and Gordon McFarlane. 2014. Harbour Publishing, P.O. Box 219, Madeira Park, BC, Canada, V0N 2H0. 400 pages, 39.95 CAD, Cloth.

OTHER

My Watery Self: Memoirs of a Marine Scientist. By Stephen Spotte. 2015. Three Rooms Press, 1700 Fourth Street, Berkeley, CA, USA, 94710. 168 pages, 15.95 USD, Paper.

The Real Thing – The Natural History of Ian McTaggart Cowan. By Briony Penn. 2015. Rocky Mountain Books, 103 – 1075 Pendergast Street, Victoria, BC, Canada, V8V 0A1. 560 pages, 49.95 CAD, Paper.

***Rare – The High-Stakes Race to Satisfy Our Need for the Scarcest Metals on Earth.** By Keith Veronese. 2014. Prometheus Books, 59 John Glenn Drive, Amherst, New York, NY, USA, 4228-2197. 270 pages, 25.00 USD, Cloth.

***Canadian Wetlands – Places and People.** By Rod Giblett. 2014. The University of Chicago Press, 1427 East 60th Street, Chicago, IL, USA, 60637. 250 pages (not illustrated), 64.00 USD, Paper.

News and Comment

Upcoming Meetings and Workshops

International Urban Wildlife Conference

International Urban Wildlife Conference hosted by the Lincoln Park Zoo's Urban Wildlife Institute and the Wildlife Society's Urban Wildlife Working Group to be held 17–20 May 2015 at the Lincoln Park Zoo, Chicago, Illinois. Registration is currently open. More information is available at http://www.urban-wildlife.org/.

Society for Freshwater Science Annual Meeting 2015

The annual Society for Freshwater Science meeting to be held 17–21 May 2015 at the Wisconsin Center, Milwaukee, Wisconsin. Registration is currently open. More information is available at http://sfsannualmeeting.org/.

Ontario Biodiversity Summit 2015

The 2015 Ontario Biodiversity Summit – the first of its kind in Ontario – to be held 19–22 May at the Marriott Gateway on the Falls, Niagara Falls, Ontario. The diverse program will focus on how to engage people, reduce threats, enhance resilience and improve knowledge via concurrent sessions, keynote speakers, networking events, a poster session and exhibit hall, and field trip activities. Registration is currently open. More information is available at http://ontariobiodiversitysummit.ca/.

Canadian Society of Ecology and Evolution Annual Meeting 2015

The 10th annual meeting of the Canadian Society of Ecology and Evolution to be held 21–25 May 2015 at the University of Saskatchewan, Saskatoon, Saskatchewan. The theme of the conference is: 'Ecology and Evolution of Managed Landscapes'. Registration is currently open. More information is available at http://csee2015.usask.ca/.

Canadian Society of Zoologists Annual Meeting 2015

The annual Canadian Society of Zoologists meeting to be held 25–29 May 2015 at the University of Calgary, Calgary, Alberta. Registration is currently open. More information is available at http://www.ucalgary.ca/csz2015/.

International Association of Great Lakes Research Annual Meeting 2015

The 58th annual meeting of the International Association of Great Lakes Research to be held 25–29 May 2015 at the University of Vermont, Burlington, Vermont. Registration is currently open. More information is available at http://www.iaglr.org/iaglr2015/.

Society of Wetland Scientists Annual Meeting 2015

The annual meeting of the Society of Wetland Scientists to be held 31 May – 4 June 2015 at the Rhode Island Convention Center in Providence, Rhode Island. The theme of the conference is: 'Changing Climate, Changing Wetlands' and will examine the role that wetlands play in the global carbon cycle, how they are affected by our changing climate and how they can provide adaptation services. Registration is currently open. More information is available at http://swsannualmeeting.org/.

Mothapalooza 2015

Mothapalooza III to be held 12–14 June 2015 at the Shawnee Lodge and Conference Center, West Portsmouth, Ohio. More information is available at http://www.mothapalooza.org/.

American Society of Mammalogists Annual Meeting 2015

The 95th annual meeting of the American Society of Mammalogists to be held 12-16 June 2015 at the Hyatt Regency Jacksonville Riverfront, Jacksonville, Florida. Registration is currently open. More information is available at https://ksuconferences.com/mammalogists/.

International Conference on Fish Telemetry 2015

The 3rd International Conference on Fish Telemetry hosted by the Ocean Tracking Network to be held 13–17 July 2015 at the World Trade and Convention Centre, Halifax, Nova Scotia. The conference will present the latest aquatic-animal telemetry research under emerging topics like transboundary issues, visualization and modelling, and intelligent open-access data. Registration is currently open. More information is available at http://2015icft.org/.

Ornithology Meeting 2015

A joint meeting of the Association of Field Ornithologists, Society of Canadian Ornithologists / Société des ornithologists du Canada, and the Wilson Ornithological Society to be held 16–19 July 2015 at Acadia University, Wolfville, Nova Scotia. Registration is currently open. More information is available at http://personalpress.acadiau.ca/ornithmeet2015/.

Botany 2015 Meeting

The annual Botany conference to be held 25–29 July 2015 at the Shaw Conference Centre, Edmonton, Alberta. This annual meeting is a multiple scientific society conference (American Bryological and Lichenological Society; American Society of Plant Taxonomists; Botanical Society of America; Plant Canada; Canadian Botanical Association; American Fern Society; International Association for Plant Taxonomy; Canadian Weed Science Society; Canadian Phytopathological Society; Canadian Society of Plant Biologists; Society of Herbarium Curators; Canadian Society of Agronomy; Canadian Society for Horticultural Science) serving over 7000 plant scientists and students whose research and practice span the globe. Registration is currently open. More information is available at http://www.botanyconference.org/.

Mycological Society of America and the Botanical Society of America Meeting 2015

A joint meeting of the Mycological Society of America and the Botanical Society of America to be held 25–29 July 2015 in Edmonton, Alberta. More information is available at http://msafungi.org/meetings/ (temporary website).

American Ornithologists' Union and Cooper Ornithological Society Meetings 2015

The annual meeting of the American Ornithologists' Union (133rd meeting) and the Cooper Ornithological Society (85th meeting) to be held 28 July – 2 August 2015 at the University of Oklahoma, Norman, Oklahoma. More information is available at http://aoucos2015.ou.edu/.

Timothy Christopher ("CHRIS") Brayshaw 1919–2014

Prominent Canadian botanist Chris Brayshaw died on December 22, 2014, age 95. He was born 2 July 1919 in Yorkshire, England, and came to Canada with his parents at the age of one. He served in the Air Force during World War II and completed his BA in biology after the war at University of British Columbia. He went to the University of Saskatchewan, where he earned an MA on 'Prairie Grassland Research' in 1950. He then returned to UBC, where, in 1954, he received a PhD with a dissertation on 'Ponderosa Pine Ecology'. Joining the Federal Government, Chris worked in Ottawa and nearby Chalk River. He joined the BC Provincial Museum in 1963. For the next forty years he advanced and promoted knowledge of B.C. plants. He prepared for the move of the museums botanical collections and facilities from the Legislature buildings to the current site. He wrote several seminal books that he exquisitely illustrated as a true nature artist and son of his mother. He helped plan and develop the new facilities and exhibits. Like many others who made a significant contribution to our knowledge of biodiversity in Canada, several of his early papers in the 1960s were published in *The Canadian Field-Naturalist*.

Abstracted from BEN (Botanical Electric News) No. 486, 28 January 2015. Which included a detailed *Victoria Times-Colonist* Obituary 17 January 2015 by Mary Lou Florian, Helen Oldershaw, and Richard Hebda, as well as "Chris Brayshaw: Memoriam" by Dr. Nancy Turner, Distinguished Professor, Environmental Studies, University of Victoria, and a bibliography by Adolf Ceska listing 27 published papers and 2 thesis. With thanks to Erich Haber for bringing this obituary to our attention.

FRANCIS R. COOK

Tributes

Book Reviews

News and Comment

Mailing date of the previous issue 128(4): 30 January 2015

THE CANADIAN FIELD-NATURALIST Volume 129, Number 1 2015

Articles

Notes

(continued on inside back cover)

ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 129, Number 2

April–June 2015

The Ottawa Field-Naturalists' Club

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Patron

His Excellency the Right Honourable David Johnston, C.C., C.M.M., C.O.M., C.M.
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

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The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

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The Manning Fund, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: An adult Snapping Turtle (*Chelydra serpentina*) from a 40-year ecological study of turtles in Algonquin Provincial Park, Ontario. See Moldowan *et al.*, pages 189–193 in this issue. Photo by Patrick Moldowan.

The Canadian Field-Naturalist

Volume 129, Number 2 April–June 2015

Using an Integrated Recording and Sound Analysis System to Search for Kirtland's Warbler (*Setophaga kirtlandii*) in Ontario

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[5]Ontario Ministry of Natural Resources, North Bay District, 3301 Trout Lake Road, North Bay, Ontario P1A 4L7 Canada
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Holmes, Stephen B., Ken Tuininga, Kenneth A. McIlwrick, Margaret Carruthers, and Eric Cobb. 2015. Using an integrated recording and sound analysis system to search for Kirtland's Warbler (*Setophaga kirtlandii*) in Ontario. Canadian Field-Naturalist 129(2): 115–120.

We used automated sound recording devices and analysis software to search for Kirtland's Warbler (*Setophaga kirtlandii*) in northeastern Ontario. In 2012, we conducted surveys at 38 locations in three Ontario Ministry of Natural Resources administrative districts: Chapleau, Sault Ste. Marie, and Sudbury. We detected a Kirtland's Warbler at one location in Sault Ste. Marie District on a single date: June 6. We believe that the recording and analysis approach we used is an effective method for detecting Kirtland's Warbler, or other rare bird species, across extensive areas of their potential range.

Key Words: Kirtland's Warbler; *Setophaga kirtlandii*; automated recording devices; sound analysis software; breeding range; northern Ontario; Algoma District

Introduction

Kirtland's Warbler (*Setophaga kirtlandii*) is an endangered species in Canada (COSEWIC 2013*) and the United States (USFWS 2014*). Kirtland's Warbler is a habitat specialist; during its breeding season, it prefers extensive tracts of young, densely stocked Jack Pine (*Pinus banksiana*) growing on well-drained sandy soils (Mayfield 1960; Walkinshaw 1983). The species also occasionally nests in stands dominated by Red Pine (*Pinus resinosa*), provided there is a Jack Pine component (Probst and Weinrich 1993; Anich *et al.* 2011; Richard 2013).

Until fairly recently, the only known breeding locality of Kirtland's Warbler was in the northern Lower Peninsula of Michigan. As a result of habitat management, aggressive control of Brown-headed Cowbird (*Molothrus ater*), and wildfires in the species' core breeding range, the Michigan population expanded considerably starting in the early 1990s (Probst and Weinrich 1993; Kepler *et al.* 1996; Donner *et al.* 2008), leading to an extension of the species' range. Small numbers of Kirtland's Warblers have nested in Michigan's Upper Peninsula since 1995 (Probst *et al.* 2003) and in Wisconsin since 2007 (Trick *et al.* 2008).

There are very few confirmed breeding records for Kirtland's Warbler in Canada. In August 1945, a pair was observed feeding a juvenile near Barrie, Ontario (Speirs 1984), although this record is dubious, because the siting was late in the breeding season, and the location was a mixed deciduous woodlot, not typical Kirtland's Warbler habitat. The best evidence of Kirtland's Warbler breeding in Canada comes from Garrison Petawawa (formerly Canadian Forces Base Petawawa) in Ontario, where six nests containing either eggs or young were found between 2007 and 2012 (Richard 2013). Kirtland's Warblers have been observed in potential breeding habitat at several other locations in Ontario and at one location in Quebec, but breeding has not been confirmed (COSEWIC 2008*).

The extensive areas of Jack Pine forest across Ontario are potential breeding habitat for the Kirtland's Warbler. If the core population in Michigan continues to increase and eventually saturates the available habitat, it is likely that the species will continue to expand into suitable habitat in Ontario (Environment Canada 2006*). Although several targeted surveys have recently been conducted in Ontario to detect breeding Kirtland's Warblers, no evidence has been found except for the nests at Garrison Petawawa (Environment Canada 2006*). However, the area searched has been relatively small compared with the potential habitat available, and it is possible that the species may be present in remote locations that have yet to be surveyed (COSEWIC 2008*).

Automated recording systems have been shown to be a useful tool for documenting the distribution of forest bird species-at-risk in highly fragmented agricultural landscapes (Holmes *et al.* 2014). They have also been recommended as a means to facilitate large-scale monitoring of birds in remote locations, such as Canada's boreal forest (Venier *et al.* 2011). The use of recordings has two potential advantages over site visits by observers in terms of documenting the presence of rare species: conducting multiple recordings on multiple days makes the detection of a rare species more likely (Holmes *et al.* 2014); and sound recordings provide a permanent record (Haselmayer and Quinn 2000) from which the species of concern can be unambiguously identified.

In this paper, we present the results of a survey conducted using automated recording devices in 2012 to determine the occupancy of apparently suitable habitat patches by one of Canada's rarest bird species, the Kirtland's Warbler.

Methods

We deployed recorders (Song Meter SM2; Wildlife Acoustics, Inc., Concord, Massachusetts, USA) at 38 locations in three Ontario Ministry of Natural Resources (OMNR) administrative districts (Chapleau, Sault Ste. Marie, and Sudbury) in northeastern Ontario (Figure 1, Table 1). In consultation with members of the Canadian Wildlife Service's Kirtland's Warbler recovery team and OMNR foresters and biologists, survey locations were chosen to be representative of potentially suitable Kirtland's Warbler habitat, i.e., Jack Pine dominated stands, less than 20 years old (Table 1). We also deployed recorders in three known Kirtland's Warbler territories in Michigan's eastern Upper Peninsula, as a check on the system's ability to detect the species.

We programmed the recorders to make eight recordings each day: a 75-min recording starting 15 minutes before sunrise; and seven, 10-minute recordings starting 75, 100, 125, 150, 175, 200, and 225 minutes after sunrise. Daily sunrise was determined by date and geographic location. The number of days that locations were surveyed varied from 5 to 38 (median 10) depending on the availability of recorders and personnel. Recordings were made at a sample rate of 24 000 Hz and saved as 16-bit pulse code modulation (PCM) wav files.

We analyzed the recordings using Song Scope version 4.1.1 automated recognition software (Wildlife Acoustics, Inc.), which uses patented algorithms to build a recognizer from training data containing samples of a species' vocalizations. Our Kirtland's Warbler recognizer was built using training data from the Borror Laboratory of Bioacoustics, Ohio State Univer-

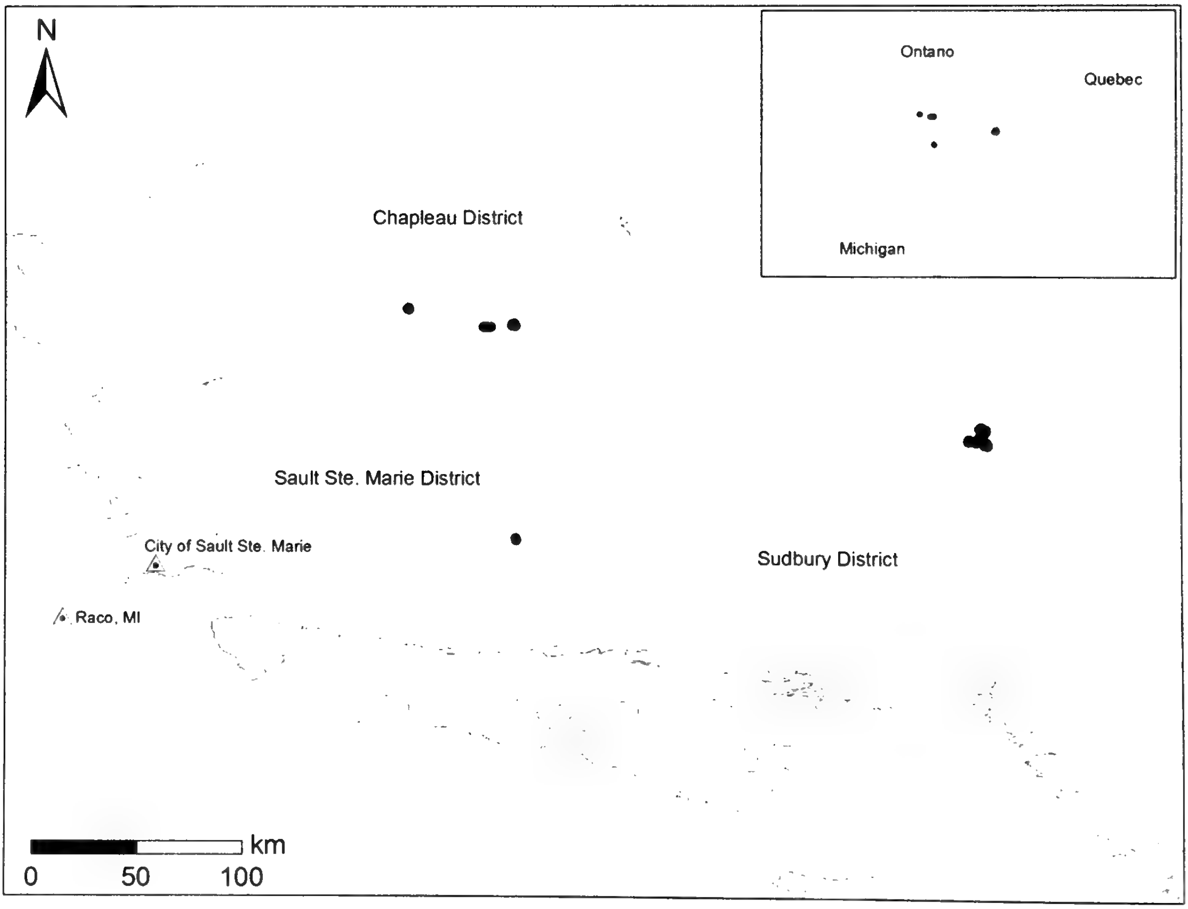

FIGURE 1. Location (black dots) of 38 sound recorders deployed to detect the Kirtland's Warbler (*Setophaga kirtlandii*) in northeastern Ontario, 1 June to 8 July 2012.

TABLE 1. Details of recordings made in potential Kirtland's Warbler (*Setophaga kirtlandii*) habitat in northeastern Ontario, Canada, 1 June to 8 July 2012.

OMNR district*	Location ID	Start date	End date	Number of recording days	Recording time (h:min.)	Stand age (years)	Stand composition†
Chapleau	Sultan2-A	1 June	8 July	38	85:10	8	Pj100
	Sultan1-C	1 June	8 July	38	85:10	9	Pj90 Sb10
	Sultan3-C	1 June	8 July	38	85:10	6	Pj100
	Sultan3-E	1 June	8 July	38	85:10	6	Pj100
	Sultan2-C	1 June	8 July	38	85:10	8	Pj100
	Sultan1-A	1 June	8 July	38	85:10	9	Pj90 Sb10
	Sultan3-D	1 June	8 July	38	85:10	6	Pj100
	Sultan3-B	1 June	8 July	38	85:10	6	Pj100
	Sultan3-A	1 June	8 July	38	85:10	6	Pj100
	Sultan2-D	1 June	8 July	38	85:10	8	Pj100
	Sultan2-E	1 June	8 July	38	85:10	8	Pj100
	Sultan2-B	1 June	8 July	38	85:10	8	Pj100
	Sultan1-B	1 June	8 July	38	85:10	9	Pj90 Sb10
Sault Ste. Marie	Algoma East	1 June	28 June	28	67:40	6	Pj34 Pr33 Sb33
Sudbury	Howey3	1 June	7 June	7	16:55	14	Pj70 Sb20 Po10
	Howey6	8 June	12 June	5	12:05	14	Pj70 Sb20 Po10
	Marconi 5	13 June	22 June	10	24:10	19	Pj80 Sb10 Po10
	Howey14	23 June	29 June	7	16:55	17	Pj70 Sb20 Po10
	Marconi1	1 June	7 June	7	16:55	14	Pj80 Sb20
	Howey9	8 June	12 June	5	12:05	14	Pj80 Sb20
	Marconi6	13 June	22 June	10	24:10	19	Pj80 Sb10 Po10
	Howey15	23 June	29 June	7	16:55	18	Pj80 Sb10 Po10
	Marconi2	1 June	7 June	7	16:55	14	Pj80 Sb20
	Marconi3	8 June	12 June	5	12:05	19	Pj80 Sb10 Po10
	Marconi7	13 June	22 June	10	24:10	18	Pj70 Sb20 Po10
	Howey12	23 June	29 June	7	16:55	17	Pj70 Sb20 Po10
	Howey4	1 June	7 June	7	16:55	14	Pj80 Sb20
	Howey8	8 June	12 June	5	12:05	14	Pj80 Sb20
	Howey10	13 June	22 June	10	24:10	14	Pj80 Sb10 Bf10
	Howey17	23 June	29 June	7	16:55	18	Pj80 Sb10 Po10
	Howey1	1 June	7 June	7	16:55	14	Pj70 Sb20 Po10
	Howey5	8 June	12 June	5	12:05	14	Pj70 Sb20 Po10
	Marconi4	13 June	22 June	10	24:10	19	Pj80 Sb10 Po10
	Howey16	23 June	29 June	7	16:55	18	Pj80 Sb10 Po10
	Howey2	1 June	7 June	7	16:55	14	Pj70 Sb20 Po10
	Howey7	8 June	12 June	5	12:05	14	Pj80 Sb20
	Howey11	13 June	22 June	10	24:10	14	Pj80 Sb10 Bf10
	Howey13	23 June	29 June	7	16:55	17	Pj70 Sb20 Po10

*OMNR = Ontario Ministry of Natural Resources.
†Stand composition based on Ontario's most recent Forest Resource Inventory; Bf = Balsam Fir (*Abies balsamea*), Pj = Jack Pine (*Pinus banksiana*), Po = Poplar sp., Pr = Red Pine (*Pinus resinosa*), Sb = Black Spruce (*Picea mariana*).

sity, Columbus, Ohio, USA (285 vocalizations from 29 individuals). Song Scope scans new recordings to produce a spreadsheet of candidate vocalizations that match the recognizer. These candidates must be examined individually (spectrogram and/or audio) to confirm the identification. See Holmes *et al.* (2014) for a full description of the process.

Results

We scanned approximately 1631 h of recordings made between 1 June and 8 July 2012 at 38 Ontario locations (Table 1). The scan produced 4129 candidate vocalizations, which required about 2 h to review. Sixty-six of 74 candidate vocalizations from a single date (6 June 2012; Table 2) at one location in the Sault Ste. Marie District (Algoma East location) were confirmed to be Kirtland's Warbler (Table 2). The first song at the Algoma East location was detected at 7:25 a.m. and the last song at 9:31 a.m. In contrast, Kirtland's Warblers recorded in Michigan sang on multiple days (range 17–29 days; Table 2), and the first song of the day was usually before sunrise (57 of 68 first songs occurred before 5:45 a.m.). The species was not detected at any locations in the Chapleau or Sudbury districts.

According to Ontario's Forest Resource Inventory, the Algoma East Kirtland's Warbler detection was in a 20.4-ha stand that had been harvested in 2005 and planted in 2006 with 34% Jack Pine, 33% Red Pine, and 33% Black Spruce (*Picea mariana*) (Table 1). In 2012, we estimated tree species composition to be 80%

TABLE 2. Detection of Kirtland's Warbler (*Setophaga kirtlandii*) at one location in Ontario (Algoma) and three locations in Michigan, 1 June to 5 July 2012.

District/county	Recorder location	Recording period	No. of days detected	No. of songs detected
Algoma, Ontario	Algoma East	1–28 June	1*	66
Chippewa, Michigan	Raco1	7 June – 5 July	29	1094
	Raco2	6 June – 5 July	22	1435
	Raco3	5–21 June	17	1388

*Kirtland's Warbler detected on 6 June 2012.

Jack Pine and 20% Red Pine, with a stem density of 2708 stems/ha. Shrub species at the site included Pin Cherry (*Prunus pensylvanica*, 20–30% cover) and willow (*Salix* spp., 0–20% cover), and ground vegetation included blueberry (*Vaccinium* spp., 30–60% cover) and Sweet-fern (*Comptonia peregrina*, 0–25% cover). The occupied stand was located in a larger area (~2500 ha) of predominantly Jack Pine forest (> 70% Jack Pine) of mixed ages and stand sizes.

Discussion

The detection of Kirtland's Warbler in Algoma East is the tenth record of the species in northern Ontario (COSEWIC 2008*; Petrucha *et al.* 2013) and only the fourth of an individual in potential breeding habitat (others were two males and one unknown; Richard 2013). The other records were for Sault Ste. Marie in 1978, Makwa Lake in Sudbury District in 1982 (potential breeding habitat), Minaki in Kenora District in 1988 (potential breeding habitat), Killarney Provincial Park in Sudbury District in 1993 and 1998, the Thessalon area in Algoma District in 1997 (potential breeding habitat), Meldrum Bay on Manitoulin Island in 2007, the Mississagi Straits in Manitoulin District in 2008, and Lake Manitou on Manitoulin Island in 2009 (COSEWIC 2008*; Petrucha *et al.* 2013).

The fact that the Kirtland's Warbler recorded in Algoma East was singing on 6 June, but not during the 5 days before or 22 days after this date, suggests two possibilities: the recording location was outside the core range of a bird that was defending a breeding territory nearby; or a bird was prospecting in the area for a mate, but was unsuccessful and moved to another location. A 1-h search of this area using playbacks on 2 June 2013 did not locate any Kirtland's Warblers (P. Burke, personal communication). The fact that this particular Kirtland's Warbler was detected on only 1 of 28 recording days in 2012 demonstrates the usefulness and power of this method. An observer-based survey conducted at this location on any other day than 6 June would not have detected the species.

The Algoma East Kirtland's Warbler record is somewhat unusual in that it was from a mixed stand of 6-year-old Jack Pine and Red Pine on a site that had been harvested in 2005 and planted with Jack Pine, Red Pine, and Black Spruce in 2006. Typical Kirtland's Warbler habitat in the core of the species range in Michigan's Lower Peninsula is homogeneous stands of 6–23-year-old Jack Pine that have regenerated after wildfire or that have been planted and managed specifically for Kirtland's Warbler (Walkinshaw 1983; Kashian *et al.* 2003; Donner *et al.* 2008). However, Kirtland's Warblers have also been reported nesting in Red Pine-dominated plantations in Wisconsin (Anich *et al.* 2011) and in mixed Jack Pine–Red Pine stands at Garrison Petawawa in Ontario (Richard 2013). The Kirtland's Warbler also prefers dense stands (stem densities > 2500 stems/ha) for nesting (Probst and Weinrich 1993), a condition that the Algoma East location did satisfy (> 2700 stems/ha).

Our survey method required minimal time in the field (about 9 days to deploy and retrieve the recorders) and did not rely on the participation of skilled observers. Problems with observer-based survey methods include: the expense and logistics involved in maintaining a crew in the field (e.g., for our study, the same level of survey effort using observers would have required hundreds of days of fieldwork); lack of availability of highly trained personnel in some regions (Hobson *et al.* 2002), which can be the case in sparsely populated areas such as northern Ontario; and differences in physical ability and skill level among observers, leading to differences in ability to detect and correctly identify birds (Rempel *et al.* 2005). Using the recording method, no skill in Kirtland's Warbler identification was necessary other than the approximately 2 h required by a single individual to review candidate vocalizations on the recordings.

Across all sites and dates, the automated scan produced a large number of false-positive detections; 4063 of 4129 candidate vocalizations (98.4%) were subsequently determined to be from species other than Kirtland's Warbler. For the eight recordings from the Algoma East location on the date the Kirtland's Warbler was detected, the false-positive rate was much lower: only 8 of 74 candidate vocalizations (10.8%) were from other species.

The scans also resulted in a large number of false negatives. Of the 323 Kirtland's Warbler vocalizations detected by visually scanning spectrograms of the 6 June Algoma East recordings (S. Holmes, unpublished data), 257 were missed by the Song Scope software for a false-negative rate of 79.6%. For a species such as the Kirtland's Warbler, which sings loudly and frequently, this large false-negative rate is probably not a major problem, if the goal is simply to determine whether the species is present. However, for more secretive species, it could lead to biased estimates of site occupancy. The false-negative rate can be reduced by increasing the sensitivity of the scan, but this would result in more false-positive detections, increasing the time required to review the candidate vocalizations (see Holmes *et al.* 2014 for details). Based on knowledge of the species and the goal of the research project, the false-positive and false-negative rates can and should be adjusted accordingly.

Both field observers and individuals listening to recordings will vary in the number of species they overlook and misidentify, with errors tending to be greater for rarer species (Campbell and Francis 2011). An advantage of the recording method, however, is that it produces a permanent record of a species occurrence that can be confirmed by reference to a library of type vocalizations or by consulting known experts (Holmes *et al.* 2014). Unambiguous identification is an important consideration in conservation planning for rare and endangered species.

We believe that the recording and analysis approach described above and elsewhere (Holmes *et al.* 2014) is a sensitive, efficient, and cost-effective method for detecting rare or uncommon bird species across extensive parts of their potential range, and it could be applied successfully in a search for breeding Kirtland's Warblers in northeastern Ontario. Given that the breeding population in Michigan has been steadily increasing, that there is a well-established breeding population in Michigan's Upper Peninsula close to Sault Ste. Marie, and that there have been two recent sightings of Kirtland's Warbler in Algoma (1997 and 2012), the likelihood that the species may expand its range into northeastern Ontario is far greater than in the past. We suggest that a systematic search of potential Kirtland's Warbler breeding habitat (6–25-year-old Jack Pine stands and mixed stands of Jack Pine and Red Pine) using 20–25 recorders over 2–3 years, and concentrating in and around the area north of the Algoma East detection would be a good next step in the search for additional Kirtland's Warblers in northeastern Ontario. The pattern of detections arising from such a survey would hopefully point to a more limited area that could be intensively searched by skilled personnel in the field.

Acknowledgements

We thank Dr. Paul Aird for his advice on potentially suitable habitat and recording locations in Chapleau District and Mr. Steve Sjogren for deploying recorders in Michigan. Recordings of Kirtland's Warbler were obtained from the Borror Laboratory of Bioacoustics, Ohio State University, Columbus, Ohio, all rights reserved.

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Received 30 April 2014
Accepted 14 February 2015

Spatial and Temporal Variation in Fish Assemblages in Three Small Unpolluted Estuarine Rivers and Associated Lagoons in Kouchibouguac National Park, Southern Gulf of St. Lawrence, Canada

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Bremner, Amanda M., D. A. Methven, Kelly R. Munkittrick, and Katherine A. Frego. 2015. Spatial and temporal variation in fish assemblages in three small unpolluted estuarine rivers and associated lagoons in Kouchibouguac National Park, southern Gulf of St. Lawrence, Canada. Canadian Field-Naturalist 129(2): 121–133.

Estuaries have among the highest primary production rates of ocean waters and provide essential habitat for many organisms. Recognition of the need to conserve these critical habitats is coupled with the need for baseline data to allow assessment of ecosystem changes. This study compares natural variations in, and correlations between, the composition of fish assemblages and environmental factors at several sites over two years in three rivers emptying into estuaries in the southern Gulf of St. Lawrence, Canada. Fish diversity and abundance were determined by beach seining and related to water temperature, salinity, substrate, and vegetation. From May to September 2000 (14 sites) and May to August 2001 (15 sites), 20 fish species were collected, seven of which accounted for 98% of the total catch. The dominant species, Mummichog (*Fundulus heteroclitus*), represented 44% of the catch. Its abundance and that of the other dominant species — Threespine Stickleback (*Gasterosteus aculeatus*) 16%, Blackspotted Stickleback (*G. wheatlandi*) 13%, Banded Killifish (*F. diaphanus*) 12%, Fourspine Stickleback (*Apeltes quadracus*) 7%, Atlantic Silverside (*Menidia menidia*) 4%, and Ninespine Stickleback (*Pungitius pungitius*) 2% — differed significantly both spatially and temporally. Multidimensional scaling analysis showed a spatial gradient in abundance from upstream to lagoon sites and a temporal gradient from spring to fall. Upstream sites were low in salinity and had a higher organic content and a higher proportion of silt–clay in the sediment. Variation within fish populations was related to site and seasonal changes in environmental conditions and species' tolerance of water temperature, salinity, vegetation coverage, and fine sediments.

Key Words: Estuary; fish; fishes; spatial and temporal gradients; beach seine; *Fundulus heteroclitus*; Mummichog; *Gasterosteus aculeatus*; Threespine Stickleback; *Gasterosteus wheatlandi*; Blackspotted Stickleback; *Fundulus diaphanus*; Banded Killifish; *Apeltes quadracus*; Fourspine Stickleback; *Menidia menidia*; Atlantic Silverside; *Pungitius pungitius*; Ninespine Stickleback; multivariate analyses; Kouchibouguac National Park; Black River; Kouchibouguac River; Kouchibouguacis River

Introduction

Although fish assemblages in shallow temperate environments are naturally highly dynamic, anthropogenic processes bring about further change through habitat modification (Waite and Carpenter 2000), introduction of non-native species (Waite and Carpenter 2000), climate change (Genner *et al.* 2010), and exploitation of commercial and bycatch species (Rogers and Ellis 2000). These impacts, caused in large part by concentration of humans in coastal zones, have resulted in disturbance and the loss of entire estuaries, which have been long recognized as among the most productive ecosystems in the world (Kennish 2000, 2002). Invertebrates and numerous species of coastal fish depend on estuaries as migration corridors, spawning and feeding habitats, and nurseries that provide refuge from predation (Haedrich 1983; Deegan and Day 1984). Conservation of estuarine habitat is critically important before more is lost (Kennish 2000, 2002).

Only a handful of fish assemblage studies have been carried out in the coastal waters of Atlantic Canada (e.g., Macdonald *et al.* 1984; Black and Miller 1991; Methven *et al.* 2001; Wroblewski *et al.* 2007; Melanson and Campbell 2012) despite the ecological and economic importance of estuaries there. Several additional studies from the southern Gulf of St. Lawrence (McKenzie 1959; Chaput 1995; Hanson and Courtenay 1995) have focused largely on the more anthropogenic influenced Miramichi River and estuary (47°5'N, 65°22'W). Research in the Miramichi estuary has concentrated on Atlantic Tomcod (*Microgadus tomcod*) as a potential indicator of the effects of pulp mill effluent (Courtenay *et al.* 1995). This estuary has important commercial and recreational fisheries for Atlantic Salmon (*Salmo salar*), American Eel (*Anguilla rostrata*), Atlantic Tomcod (*Microgadus tomcod*), Rainbow Smelt (*Osmerus mordax*), and Gaspereau (*Alosa* spp.) and contains approximately 78 species of fishes (McKenzie 1959; Chaput 1995; Hanson and Courtenay 1995). Robinson *et al.* (2001) collected 21 fish taxa using beach seine nets in the Kouchibouguac and Richibucto estuaries while looking for spawning grounds of Striped Bass (*Morone saxatilis*). Thériault *et al.* (2006, 2007) also sampled in the southern Gulf of St. Lawrence, collecting 18 species adjacent to fish processing plants. The coastal fauna is further described by ichthyoplankton surveys of the Miramichi, Kouchibouguac, and Richibucto estuaries (Locke and Courtenay 1995; Robinson *et al.* 2001) and bottom trawling (< 40 m) in the Northumberland Strait (Bosman *et al.* 2011).

Our study examines the fish assemblages in a near-pristine environment, Kouchibouguac National Park in the southern Gulf of St. Lawrence. This is among the first studies undertaken in a shallow estuarine habitat where near-natural undisturbed conditions exist.

Although we acknowledge that it is difficult to characterize pristine conditions, given the long history of exploitation and habitat modification in estuaries (Blaber *et al.* 2000), anthropogenic impacts in the study area are limited to commercial fishing of a few species, notably *A. rostrata, O. mordax* (during winter), and *Alosa* spp. (Kalff 1998) and occasional dredging. There is no industry or fish processing facility, farming, pesticide use, wood cutting, or disposal of domestic sewage that would affect the estuary or nearby waters. The last shipyard for boat building and repair closed in 1868. Canneries closed in the 1950s, and sawmill operations ceased in 1964 (Beach 1988; Rudin 2011).

Our study is unique in that it reports changes in fish assemblages at upstream, downstream, and lagoon sampling sites during spring, summer, and fall in three relatively pristine rivers over 2 years. The objective was to describe variation in these assemblages among sites (15), rivers (3), seasons (3), and years (2) in relation to environmental and habitat variables.

Study Area

All sampling occurred in vegetated areas within or immediately adjacent to Kouchibouguac National Park on the east coast of New Brunswick, Canada, bordering on the southern Gulf of St. Lawrence. Kouchibouguac National Park is representative of the Maritime Lowland Ecoregion and includes bogs, salt marshes, tidal rivers, freshwater systems, sheltered lagoons, abandoned fields, and Acadian forests (Rowe 1972; Beach 1988). Aquatic habitat within the park is relatively undisturbed (Hauck *et al.* 2009), and the amount of disturbance has decreased each year since the park was established in 1979 (Beach 1988; Kalff 1998).

All sampling was confined to the Black, Kouchibouguac, and Kouchibouguacis Rivers and their associated estuaries and lagoons (Figure 1). These rivers

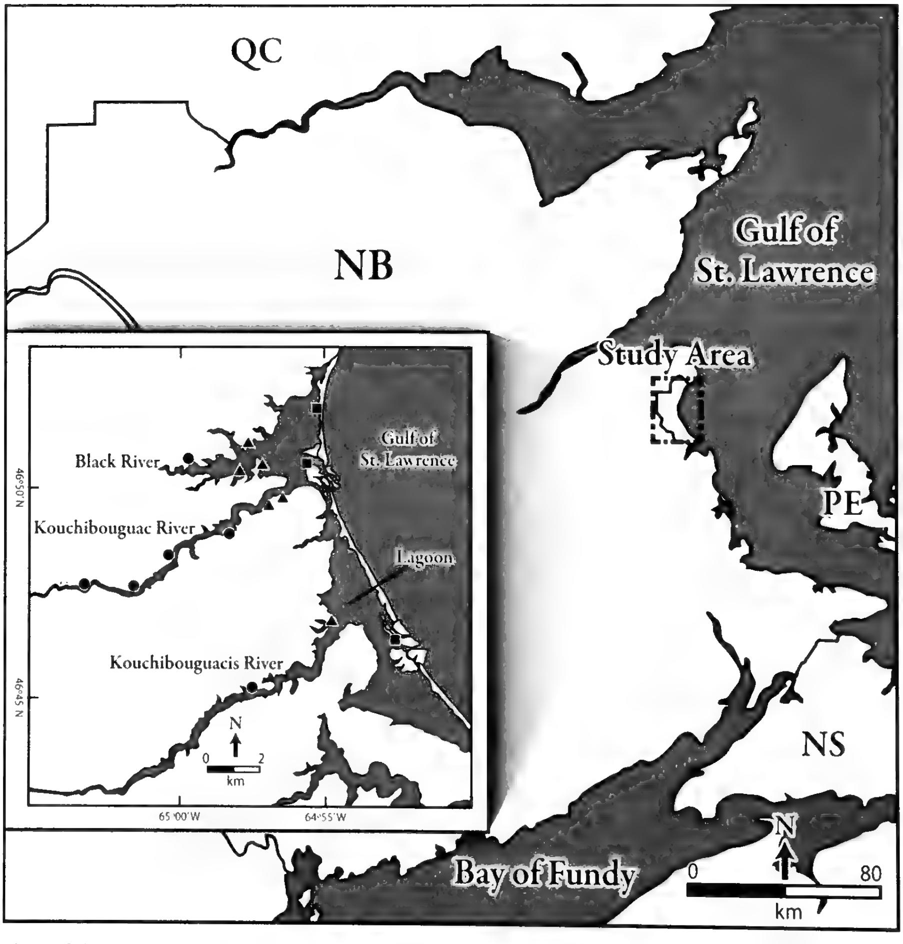

FIGURE 1. Location of the 15 sampling sites in the coastal waters of the southern Gulf of St. Lawrence, New Brunswick, in or adjacent to Kouchibouguac National Park, showing upstream (●), downstream (▲), and lagoon (■) sites. The lagoon site at the mouth of the Kouchibouguacis River was added in 2001. Note: NB = New Brunswick, NS = Nova Scotia, QC = Quebec, PE = Prince Edward Island.

form broad shallow (< 10 m) estuaries that are protected from the ocean by a series of barrier islands (Beach 1988; Hauck *et al.* 2009). Sediments vary from silt and mud upstream to sand in the lagoons. Vegetation also varies with distance from the ocean. Sea Ditchgrass (*Ruppia maritima*) dominates upstream areas, and Common Eelgrass (*Zostera marina*) is characteristic of the parts of the rivers and lagoons affected by tides (Beach 1988). The mixed semi-diurnal tides that characterize the region have an amplitude of approximately 3 m (Miller *et al.* 1991; Robinson *et al.* 2001). Hauck *et al.* (2009) has described the study area in more detail. The Kouchibouguac River lagoon site has been studied previously (Joseph *et al.* 2006).

The salinity of upstream sampling sites ($n = 6$), greater than 2 km from the mouth of the river, was less than 10 ppt. That of downstream sites ($n = 6$), which were less than 2 km from the mouth of the river, was 10–25 ppt. Lagoon sites ($n = 3$), located on the western side of the barrier islands were characterized by salinities greater than 25 ppt.

Methods

Fish sampling

Fourteen sites were sampled from May to September 2000. In 2001, sampling was repeated from May to August with the addition of a 15th site: the southernmost lagoon site on the Kouchibouguacis River (Figure 1). Sites were sampled once a month to minimize impact on beds of eelgrass and fish mortality. Each site was sampled using a 30 m × 1.3 m beach seine (6-mm mesh throughout), with 69 hauls in 2000 and 60 in 2001 to a maximum depth of 1.2 m.

The beach seine was deployed by pulling half the net perpendicular to the shore until the collection bag was in the water, then pulling it parallel to the shore against the current until the entire seine was in the water. The deep end of the seine was then brought back to shore 10 m from the starting point. The seine was hauled out of the water simultaneously by two people who gradually approached each other to close the seine. When the seine was deployed from a boat (at the nine lagoon sites), the same procedure was employed; however, the seine was pulled into the boat rather than onto the shore. The catch efficiency was judged to be consistent given that the vast majority of the catch was confined to the centrally located collection bag, making it easy to retain the catch and haul it into the boat.

The catch was carefully emptied into a plastic tub (51 cm × 43 cm × 25 cm) filled with water from the collection site. Fish were identified and counted, and the vast majority were returned to the water alive. Fish were identified to species using Scott and Crossman (1973) and Scott and Scott (1988). In the few cases where a seine haul captured more than 300 individuals of one species (in 2000, 9 of 69 hauls; in 2001, 6 of 60 hauls), a dip net was used to subsample 300 individuals to minimize handling and holding stress.

Environmental variables

Data on salinity, temperature, organic content, silt clay content, and plant and algae cover were collected at each site to examine relationships with seasonal and spatial variability. Vegetation coverage was determined by random toss of a metal quadrat (54 cm × 54 cm), repeated three times at each sampling site. The quadrat was divided into four equal quadrants, and plant and algal cover were estimated separately for each quadrant through a viewing box with a plexiglass bottom. The percentage cover was calculated as the average of the 12 quadrants.

Approximately 200 mL of sediment was collected at each site, using a garden trowel, to determine percentage organic content and percentage silt–clay. Sediment samples were placed in a plastic bag and frozen (−20°C) until lab analysis was conducted as described by Higgins and Thiel (1988) and Thériault *et al.* (2006). Water temperature and salinity were measured at a depth of 0.5 m approximately 2 m from shore.

Data analyses

Univariate and multivariate analyses were used to determine variation in catches of fishes and environmental variability (salinity, temperature, organic content, silt–clay, plant and algae cover) among sampling locations (upstream, downstream, lagoon), rivers (Black, Kouchibouguac, Kouchibouguacis), seasons (spring [May], summer [June, July], fall [late August, September]), and years (2000, 2001).

Significant differences among rivers, sampling locations, seasons, and years were determined using the global nonparametric Kruskal–Wallis test for species richness and total abundance (SAS 2000). Significant differences among sampling locations and seasons were determined using the nonparametric Kruskal–Wallis test for the seven most abundant species (i.e., those representing more than 1% of the total catch) and the six environmental variables (SAS 2000). This test is an analysis of variance of ranked data used to compare more than two samples (Zar 1996). It was followed by the Wilcoxon paired test to determine where significant differences occurred between upstream and downstream, upstream and lagoon, downstream and lagoon locations and between spring and summer, spring and fall, and summer and fall, for the mean species richness, mean total abundance, mean abundance of each dominant fish species, and the six environmental variables. Because only 2 years were sampled, the Wilcoxon test was used to test for differences between years.

All fish assemblage data were submitted to multidimensional scaling (MDS) analysis (Clarke and Warwick 2001) based on the Bray Curtis similarity index to identify patterns in abundance by site and season. The Bray–Curtis similarity index was chosen over other common indices because it is recommended for species data and depends only on those species that are present (it does not take into account joint absences) (Clarke 1993).

MDS analysis was based on relative species abundance for each site and month, i.e., species abundance was expressed as a percentage of the total abundance for that site and month. We used relative abundance because of the unequal number of samples collected in different years, months, and locations. Species data were square root transformed. Environmental data were analyzed using correlation-based principal components analysis (PCA) with normalized Euclidean distance as the measure of distance between samples (Clarke and Warwick 2001). This analysis is the most appropriate for mixed measurement scales characteristic of environmental data (e.g., organic content as a percentage, salinity as parts per thousand, etc.). For the multivariate analyses, rivers and years were pooled because no significant differences were found in mean species richness and mean total abundance among the rivers or between years.

Correlations between ranked mean species abundances and ranked environmental variables were determined using the Spearman correlation test (SAS 1999). All analyses were conducted with $\alpha = 0.05$.

Results

Fish assemblage

More than 21 000 fish (11 022 in 2000 and 10 131 in 2001) representing 20 taxa from 13 families were collected in the 129 samples taken from the three estuarine rivers and associated lagoons (Table 1). Seven estuarine species accounted for 98% of the catch: *Fundulus heteroclitus* (44%) was the most abundant, followed by four species of sticklebacks, *Gasterosteus aculeatus* (16%), *G. wheatlandi* (13%), *Apeltes quadracus* (7%), and *Pungitius pungitius* (2%), in addition to *F. diaphanus* (12%) and *Menidia menidia* (4%). All fishes were small bodied (usually less than 30 cm in length) and these seven dominant species were represented by both juvenile and adult stages.

TABLE 1. Number of fishes (n = 21 153) caught in three estuaries in Kouchibouguac National Park, southern Gulf of St. Lawrence, in spring, summer, and fall 2000 and 2001.

	Abundance	
Species	Number	%
Mummichog (*Fundulus heteroclitus*)	9313	44.03
Threespine Stickleback (*Gasterosteus aculeatus*)	3302	15.61
Blackspotted Stickleback (*G. wheatlandi*)	2784	13.16
Banded Killifish (*Fundulus diaphanus*)	2615	12.36
Fourspine Stickleback (*Apeltes quadracus*)	1522	7.20
Atlantic Silverside (*Menidia menidia*)	849	4.01
Ninespine Stickleback (*Pungitius pungitius*)	489	2.31
Striped Bass (*Morone saxatilis*)	75	0.35
Smooth Flounder (*Liopsetta putnami*)	65	0.31
Winter Flounder (*Pseudopleuronectes americana*)	57	0.27
Atlantic Tomcod (*Microgadus tomcod*)	19	0.09
Brook Trout (*Salvelinus fontinalis*)	16	0.08
Golden Shiner (*Notemigonus crysoleucas*)*	13	0.06
Cunner (*Tautogolabrus adspersus*)	12	0.06
Gaspareau, Blueback, Shad (*Alosa* spp.)	9	0.04
Juvenile flounder (*Pleuronectes* spp.)	7	0.03
White Sucker (*Catostomus commersonii*)	3	0.01
Yellowtail Flounder (*Limanda ferrugina*)	1	0.00
Northern Pipefish (*Sygnathus fuscus*)	1	0.00
Longhorn Sculpin (*Myoxocephalus octodecemspinosus*)	1	0.00

*Identification tentative.

Species richness (Kruskal–Wallis test: $\chi^2 = 0.6413$, $P = 0.73$) and total catches (Kruskal–Wallis test: $\chi^2 = 1.6767$, $P = 0.43$) were not significantly different among the three rivers sampled. However, species richness (Kruskal–Wallis test: $\chi^2 = 28.7267$, $P < 0.0001$) and total catch (Kruskal–Wallis test: $\chi^2 = 21.8753$, $P < 0.0001$) did differ significantly among upstream, downstream, and lagoon locations (Figure 2). Species richness (Wilcoxon test: $\chi^2 = 1.7492$, $P = 0.20$) and total catches (Wilcoxon test: $\chi^2 = 0.1826$, $P = 0.68$) were not significantly different between years. Species richness (Kruskal–Wallis test: $\chi^2 = 0.34$, $P = 0.84$) and total catches (Kruskal–Wallis test: $\chi^2 = 1.3380$, $P = 0.51$) were also not significantly different among seasons (Figure 2).

Abundance patterns of the dominant species differed significantly among sites and seasons (Figure 3). Catches of *P. pungitius*, *F. heteroclitus* and *F. diaphanus* decreased significantly from upstream to lagoon sites. Catches of *A. quadracus* between upstream and downstream sites were not significantly different, but they were significantly lower at lagoon sites. Mean catches

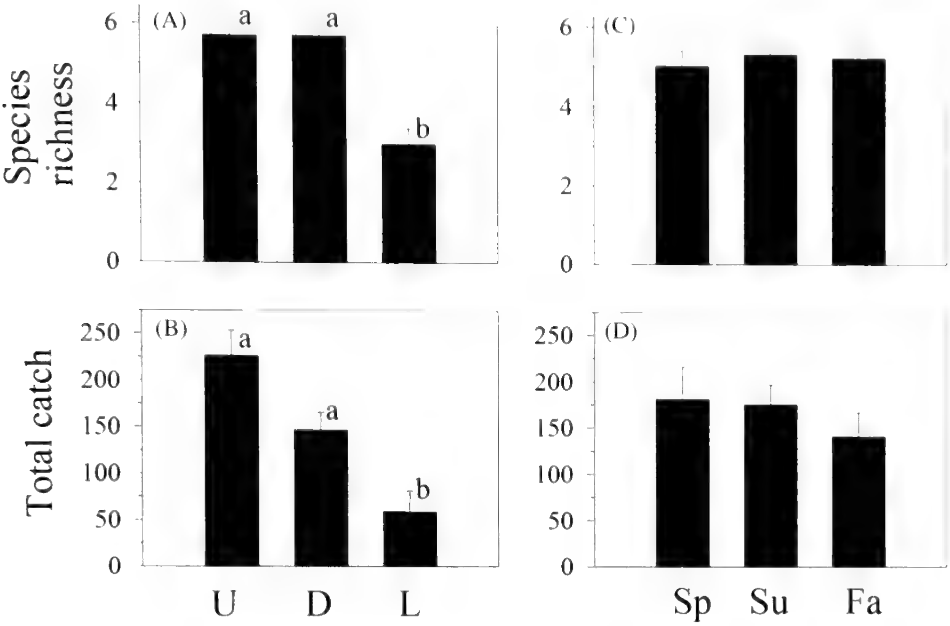

FIGURE 2. (A) Mean species richness and (B) mean total beach seine catch at upstream (U), downstream (D), and lagoon (L) sampling sites, and (C) mean species richness and (D) mean total beach seine catch in spring (Sp), summer (Su), and fall (Fa) in Kouchibouguac National Park estuaries, southern Gulf of St. Lawrence (n = 129). Significant differences are indicated by different letters (a, b).

of *G. aculeatus* and *M. menidia* were lower at upstream sites, peaked at downstream sites, and decreased slightly in the lagoon although not all these differences were significant. Relative abundances of *G. wheatlandi* did not vary among upstream, downstream, and lagoon sites (Figure 3).

Four patterns of species abundance were evident by season (Figure 3): catches of *G. aculeatus* and *G. wheatlandi* decreased significantly from spring to fall; catches of *A. quadracus* and *P. pungitius* increased significantly from spring to fall; catches of *F. heteroclitus* and *F. diaphanus* were lowest in spring and highest in summer, a trend that was only significant for *F. diaphanous*. *Mendia menidia* was less abundant in summer, although not significantly.

Environmental variables

Salinity (Kruskal–Wallis test: χ^2 = 29.6549, P < 0.0001) was the single variable that differed significantly by river; it was lower in the Kouchibouguac River than in the Black and Kouchibouguacis Rivers. Organic content (Kruskal–Wallis test: χ^2 = 2.2614, P = 0.32) and silt–clay content (Kruskal–Wallis test: χ^2 = 5.0094, P = 0.082) of the sediment and algae coverage (Kruskal–Wallis test: χ^2 = 2.9104, P = 0.23) were marginally (but not significantly) lower in the Black River. Temperature (Kruskal–Wallis test: χ^2 = 0.2923, P = 0.86) and plant coverage (Kruskal–Wallis test: χ^2 = 1.1577, P = 0.56) were relatively homogeneous in all three rivers.

Salinity was significantly higher (Wilcoxon test: χ^2 = 12.5276, P = 0.0004) in 2001 than in 2000. Organic content (Wilcoxon test: χ^2 = 10.4476, P = 0.0012) and plant coverage (Wilcoxon test: χ^2 = 10.8755, P = 0.0010) were significantly lower in 2001. Temperature (Wilcoxon test: χ^2 = 1.9977, P = 0.17), silt–clay content (Wilcoxon test: χ^2 = 0.0008, P = 0.99), and algae coverage (Wilcoxon test: χ^2 = 0.2283, P = 0.63) did not differ between years.

As expected, salinity increased significantly from upstream to lagoon sites (Figure 4). Salinity was lowest in spring when terrestrial runoff was highest and significantly higher in summer and fall. Water temperature ranged from 8° to 28°C (mean 20.1°C) throughout the study and differed significantly among seasons: lowest in spring, highest in summer, and intermediate in fall. Temperature did not differ significantly among upstream, downstream, and lagoon locations.

Organic content in the sediment ranged from 0.25% to 14.93% (mean 2.21%); it was highest upstream and decreased significantly toward lagoon sites (Figure 4). Organic content did not differ significantly among seasons. Silt–clay content of the sediment ranged from 0.04% to 32.23%, (mean 4.93%) and followed the same pattern as organic content: highest at upstream sites and lowest in the lagoon. Silt–clay content did not differ among seasons.

Plant cover ranged from 0% to 95% (mean 33%). Coverage was highest at downstream sites and lowest

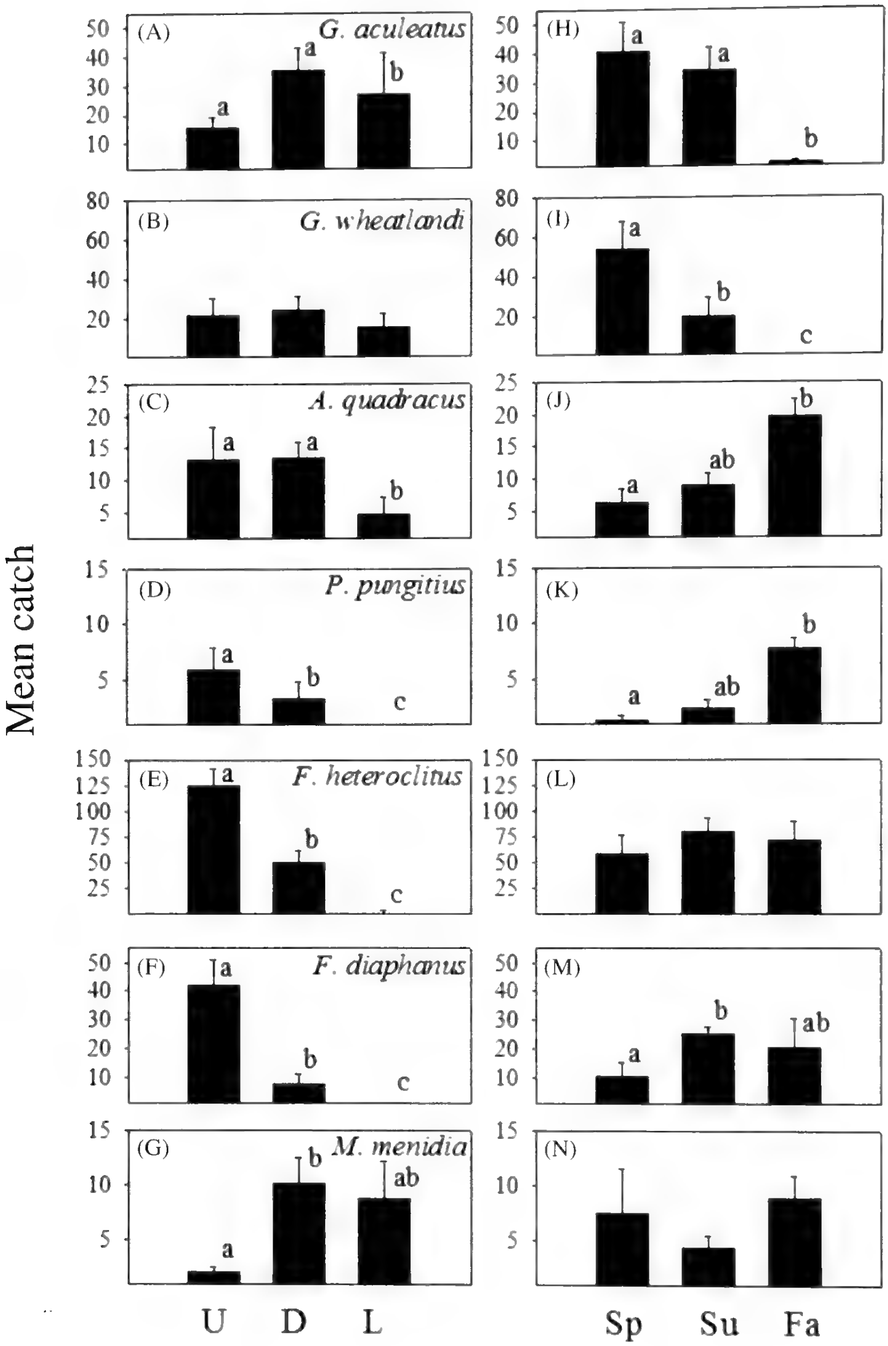

FIGURE 3. Mean catch of dominant fish (one standard error) (A–G) at upstream (U), downstream (D), and lagoon (L) sampling sites, and (H–N) in spring (Sp), summer (Su), and fall (Fa) in Kouchibouguac National Park estuaries, southern Gulf of St. Lawrence (*n* = 129). Significant differences are indicated by different letters (a, b, c).

in high–salinity lagoon sites (Figure 4). Plant coverage was significantly lower in spring than in summer or fall. Algal coverage reached a maximum of 65% (mean 9%) and was highest at upstream sites and lowest at lagoon sites, although this difference was not significant. Algal coverage was significantly lower in spring compared with summer and fall.

Linking fish assemblages to environmental variables

Two fish assemblage patterns, based on species composition and catches, were apparent from the MDS analysis: a spatial gradient from low salinity upstream sites to higher salinity lagoon sites (Figure 5a) and a temporal gradient from spring to fall (Figure 5b). PCA of all the environmental variables (salinity, temperature,

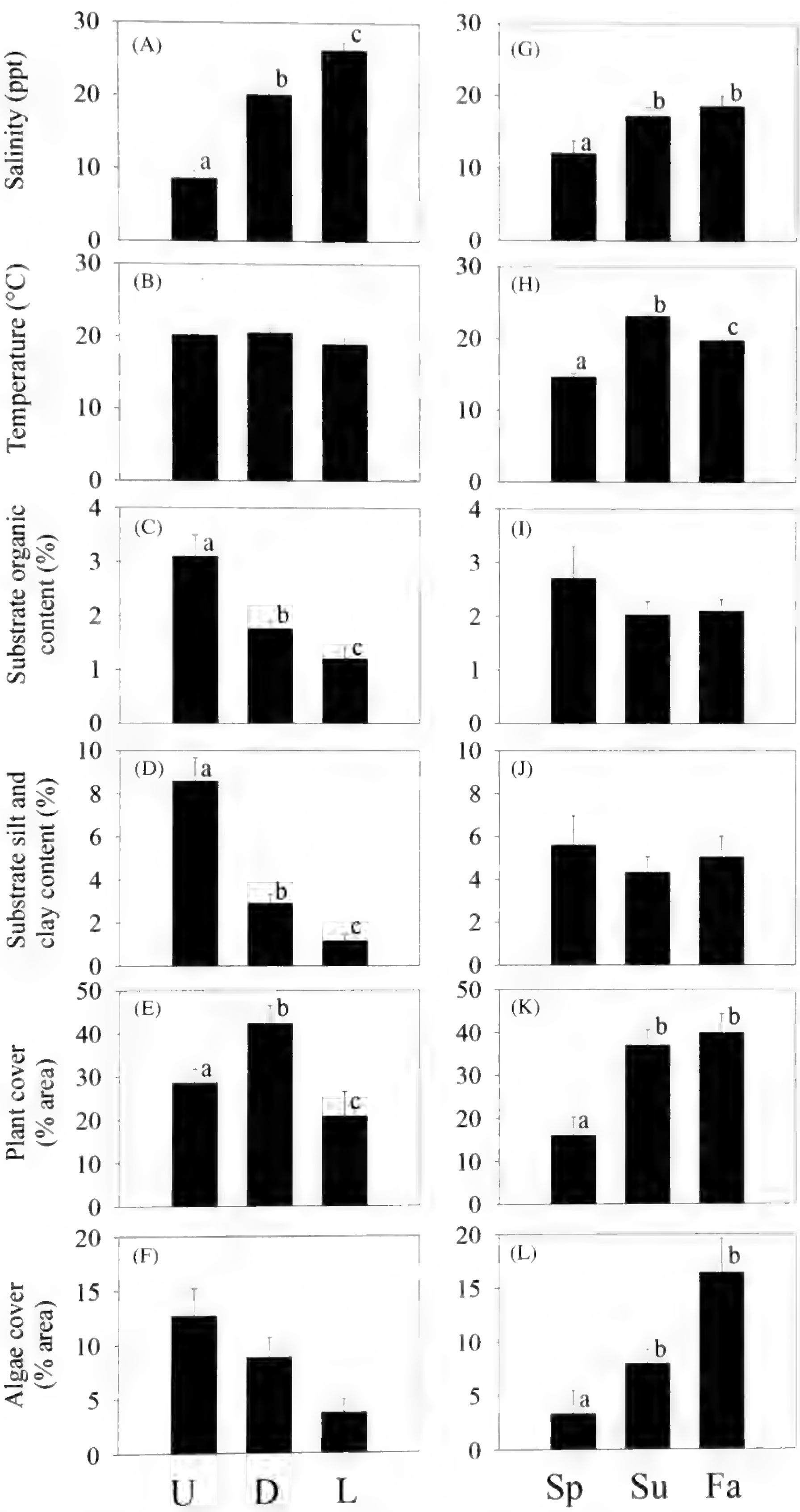

FIGURE 4. Environmental variables (mean and one standard error) (A–F) at upstream (U), downstream (D), and lagoon (L) sampling sites and (G–L) in spring (Sp), summer (Su), and fall (Fa) in Kouchibouguac National Park estuaries, southern Gulf of St. Lawrence ($n = 129$). Significant differences are indicated by different letters (a, b, c).

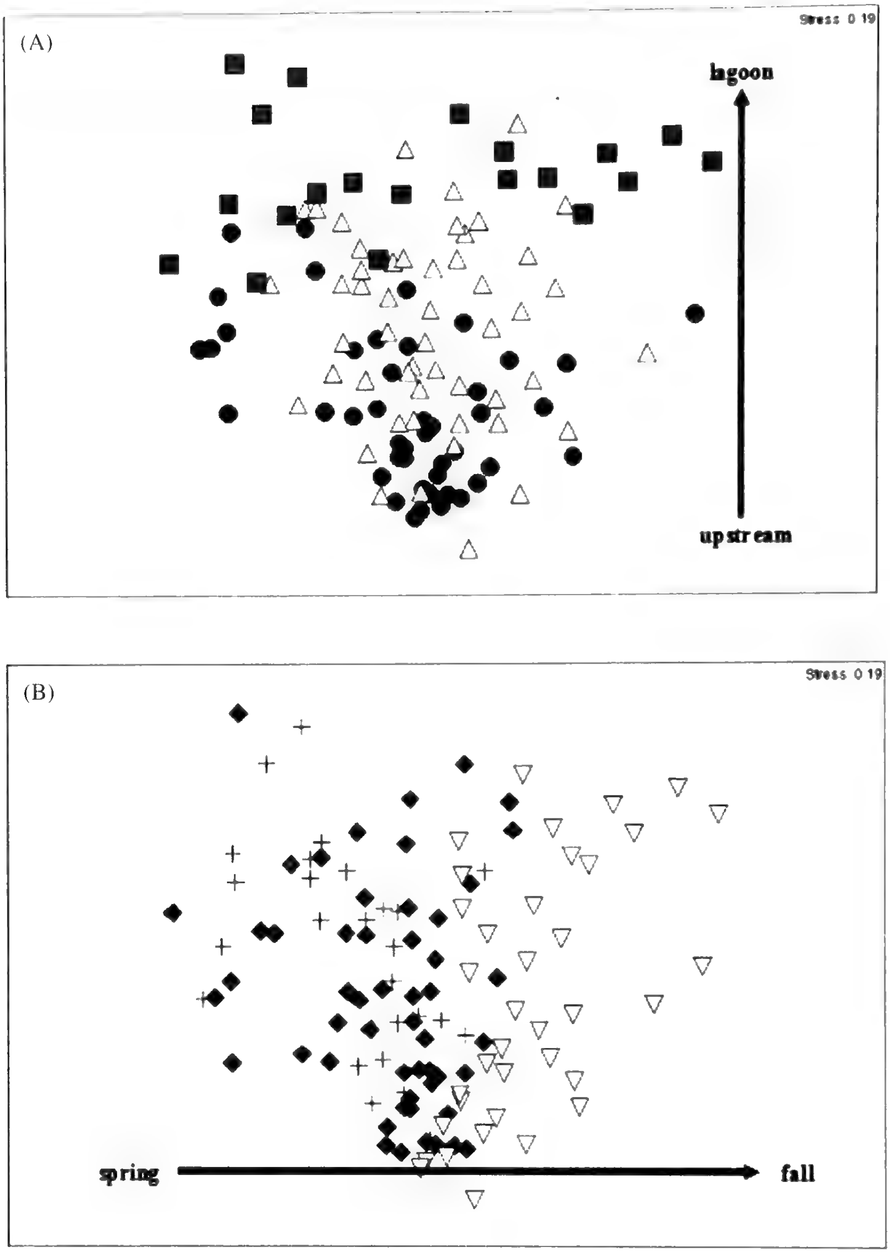

FIGURE 5. Multidimensional scaling (MDS) ordination plots of fish assemblage data showing spatial gradient from (A) upstream (●), downstream (△), and lagoon (■) sites and temporal gradient from (B) spring (+), summer (♦), and fall (▽) samples in Kouchibouguac National Park estuaries, southern Gulf of St. Lawrence ($n = 129$).

organic content, silt–clay content, plant coverage and algae coverage) showed two similar gradients: from upstream to lagoon sites on axis 1 (Figure 6a, 34.9% variation) and from spring to fall on axis 2 (Figure 6b, 24.5% of the variation). The remaining PCA axes did not contribute significantly in the analysis.

Significant correlations were detected between catches of the seven dominant fishes and the six environmental variables. Catches were significantly correlated with salinity, except those of *G. wheatlandi* and *A. quadracus* (Table 2). These correlations were negative for all species except *M. menidia*. Temperature was significantly correlated with catches of *G. wheatlandi* (negative) and both *Fundulus* species (positive).

The catches of *P. pungitius*, *F. heteroclitus*, and *F. diaphanus* were positively correlated with organic and silt–clay content. Catches of *M. menidia* were negatively correlated with silt–clay content (Table 2). The catches of all species except *G. wheatlandi* were positively correlated with vegetation coverage: *G. aculea-*

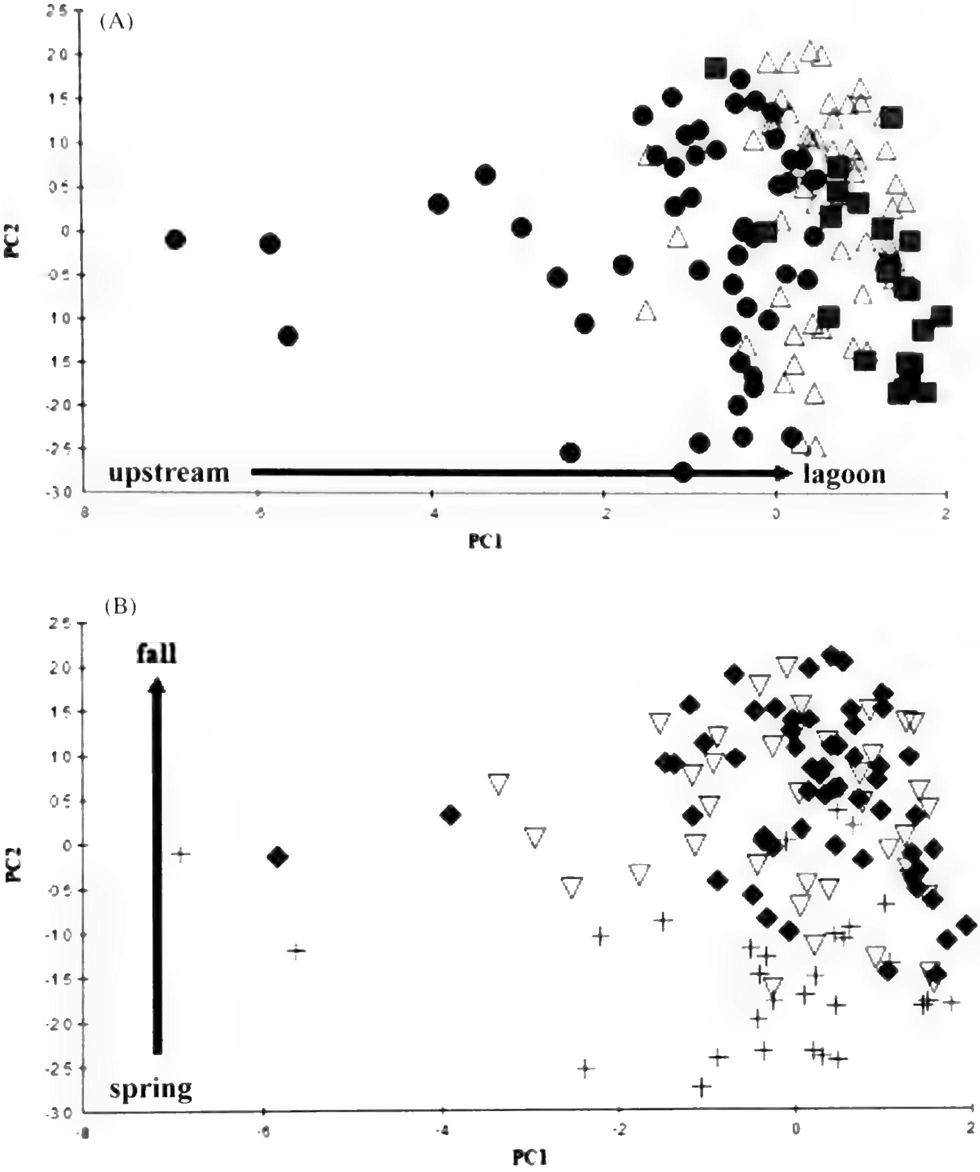

FIGURE 6. Principle component analysis (PCA) ordination plots of environmental data showing spatial gradient from (A) upstream (●), downstream (△), and lagoon (■) sites and temporal gradient from (B) spring (+), summer (♦), and fall (▽) samples in Kouchibouguac National Park estuaries, southern Gulf of St. Lawrence ($n = 129$). Samples are plotted on the first two PCA axes, which capture 34.9% (axis 1) and 24.5% (axis 2) of variation.

TABLE 2. Spearman ranked correlations (range: -1 to 1) between environmental variables and fish species catches in Kouchibouguac National Park estuaries, southern Gulf of St. Lawrence. Significant correlations are in bold type.

Species	Salinity	Temperature	Organic content	Silt-clay content	Plant cover	Algae cover
Threespine Stickleback (*Gasterosteus aculeatus*)	**-0.205**	0.125	0.123	0.071	**0.178**	-0.087
Blackspotted Stickleback (*G. wheatlandi*)	-0.044	**-0.184**	-0.146	-0.031	-0.036	-0.023
Fourspine Stickleback (*Apeltes quadracus*)	-0.018	0.163	0.136	0.169	**0.418**	**0.228**
Ninespine Stickleback (*Pungitius pungitius*)	**-0.280**	0.002	**0.238**	**0.284**	**0.199**	0.030
Atlantic Silverside (*Menidia menidia*)	**0.241**	0.102	-0.068	**-0.275**	**0.237**	0.162
Mummichog (*Fundulus heteroclitus*)	**-0.197**	**0.286**	**0.227**	**0.486**	0.149	**0.267**
Banded Killifish (*Fundulus diaphanus*)	**-0.341**	**0.279**	**0.282**	**0.482**	0.069	0.116

tus, *A. quadracus*, *P. pungitius* and *M. menidia* showed a positive correlation with plant coverage, and *A. quadracus* and *F. heteroclitus* showed a positive correlation with algae coverage.

Discussion

Conservation of estuarine habitats is essential, as these habitats are among the most productive in the ocean and provide essential nursery habitat for many organisms, including commercially important fish and species at risk. Our study of shallow estuarine habitats in near-undisturbed conditions in the southern Gulf of St. Lawrence differed from a survey of the more anthropogenically disturbed Miramichi Estuary, approximately 30 km to the north. There, Hanson and Courtenay (1995) reported 47 species (compared with our 20), 18 of which were found in this study. The Miramichi study covered a larger area, included both shallow and deep water, involved a variety of sampling equipment, and took place throughout the year, all of which resulted in greater species richness. Golden Shiner (*Notemigonus crysoleucas*) and Northern Pipefish (*Syngnathus fuscus*) were two rare species taken in our study that were not reported by Hanson and Courtenay (1995) but were reported previously from estuarine waters of the southern Gulf of St. Lawrence (Needler 1940 [as *Siphostoma fuscum*]; Robinson *et al.* 2001; Herrell and Methven 2009). Otherwise, all fish species collected in our study have been reported previously from shallow coastal waters of the southern Gulf of St. Lawrence (Beach 1988; Robinson *et al.* 2001; Joseph *et al.* 2006).

The relatively small number of species (20) captured by seining and the high catches of just a few species (seven species represent 98% of the fishes caught) in our study are typical of fish assemblages in temperate estuaries off eastern Canada and New England (Lazzari *et al.* 1999; Methven *et al.* 2001; Joseph *et al.* 2006; Thériault *et al.* 2006; Herrell and Methven 2009; Furey and Sulikowski 2011; Teather *et al.* 2012). Species richness in shallow waters such as those sampled by beach seine off Atlantic Canada south of Newfoundland and Labrador is typically less than 25, with most fish species belonging to the Fundulidae, Gasterosteidae, Gadidae, Pleuronectidae, Clupeidae, Cottidae, and Osmeridae. This fauna is a mixture of north temperate and boreal species (Haedrich 1983). Species richness generally increases with additional inshore habitats, sampling gear types, water depth, seasons, tide, and diel cycles (e.g., Hanson and Courtenay 1995). Nonetheless, the shallow water (beach seine) fish assemblages off eastern Canada from Newfoundland and Labrador to New England can be characterized by relatively small body size (less than approximately 30 cm total length), a high proportion of juveniles (that use the area as a nursery) and small adult fishes (that use the area for feeding and spawning), low species richness (< 25), and few species (typically < 7) contributing to more than 90% of the total catch. Many of these shallow water fishes spawn demersal eggs (Pearcy and Richards 1962; Methven *et al.* 2001).

The environmental variables that differed significantly between years were salinity (higher in 2001) and the percentage of organic content and plant cover (both lower in 2001). The higher salinity was likely due to greater precipitation from October 1999 to April 2000 (776.3 mm) before the sampling season, causing greater freshwater runoff compared with precipitation from October 2000 to April 2001 (638.4 mm). The lower plant coverage in 2001 might be related to the lower organic content, as fewer nutrients in the substrate would limit plant growth. The lower level of organic content was probably related to the lower level of precipitation and less freshwater runoff.

The only environmental variable that differed significantly among rivers was salinity, which was lower in the Kouchibouguac River. Even though there were some significant differences in environmental variables between years and/or rivers, mean species richness and total fish abundance did not differ significantly.

The seven dominant fishes sampled in our study (two Fundulidae, four Gasterosteidae, and one Atherinopsidae) responded to a seasonal gradient and a spatial lagoon-to-upstream gradient (salinity was lower and organic content and proportion of silt–clay in the substrate were higher at upstream sites). Dominant species were present at all sites, except for *F. diaphanus* which was never captured in the high-salinity lagoon sites. *Fundulus diaphanus, P. pungitius*, and *F. heteroclitus* were all significantly negatively correlated with salinity. Salinity has a strong influence on abundance of *F. heteroclitus* and *F. diaphanus* (Fritz and Garside 1974). These three species, were also significantly and positively correlated with organic and silt–clay content and, consequently, decreased in abundance toward the lagoon. The high proportions of silt–clay and organic material at upstream sites contributed to softer and more easily disturbed sediments, which likely increased suspended sediment in the water column. *Fundulus heteroclitus* often occurs in muddy habitats where it tolerates low oxygen levels (Scott and Scott 1988; Halpin and Martin 1999; Collette and Klein-MacPhee 2002; Stierhoff *et al.* 2003).

Fundulus heteroclitus spawns during summer, at approximately 19°C (McMullin *et al.* 2009) when our catches were highest (although they were not significantly different from those in spring and fall). The available evidence indicates an absence of lunar spawning in *Fundulus heteroclitus macrolepidotus*, the subspecies characterizing the northern distribution of the Mummichog. The spawning process is likely largely regulated by temperature (McMullin *et al.* 2009). *Fundulus heteroclitus* is abundant in relatively protected sites in the southern Gulf of St. Lawrence, an observation that contrasts with studies from the coastal Bay of Fundy, where it is present but seldom reported in high abundance (Macdonald *et al.* 1984; Arens 2007), due possibly to the more exposed nature and higher salinity of the Bay of Fundy sampling sites. McMullin *et al.* (2010) caught *F. heteroclitus* at relatively protected sites in low-salinity water (e.g., 6 ppt–22 ppt) in the lower St. John River, which empties into the Bay of Fundy.

We found *F. diaphanus* to be most abundant at upstream sites, where its presence was significantly correlated with salinity and temperature. The negative correlation with salinity is in keeping with previous studies: Murdy *et al.* (1997) observed that it rarely occurred where salinity was greater than 5 ppt; according to Griffith (1974) and Fritz and Garside (1974), it inhabits freshwater streams and lakes and only rarely invades brackish or marine waters. Catches of *F. diaphanus* were greatest during summer when it spawns (Fritz and Garside 1975). Eggs are reported to be suspended below the female by chorionic filaments, which can attach to aquatic vegetation once fertilized (Richardson 1939; Able and Fahay 2010). Although *F. diaphanus* inhabits upstream sites with aquatic vegetation, it was not significantly correlated with either plant or algae cover, in contrast with the findings of Scott and Crossman (1973: 633) who noted: "Small schools are usually found over sand, gravel, or detritus-covered bottom where there are patches of submerged aquatic plants." Instead, we observed a strong positive correlation with fine sediments, which have been reported as a suitable substrate for burrowing to escape from predation, as noted by Colgan and Costeloe (1980) in laboratory studies.

Menidia menidia is a short-lived (< 2 years) schooling species inhabiting coastal habitats with a sandy bottom and high salinity (Scott and Scott 1988; Able and Fahay 1998). It was most abundant in lagoon and downstream locations, where catches were highest in spring and fall. Low abundance in summer was consistent with observations by Arens (2007) at six sites in the Bay of Fundy. This seasonal pattern of small summer catches was interpreted by Doyle *et al.* (2011) as movement from nursery grounds in late spring and early summer to spawning grounds. Spawning grounds are apparently located in intertidal areas, including marsh creeks and tidal channels, where eggs (1–1.5 mm in diameter) are deposited at high tides on aquatic plants and algae by means of a tuft of adhesive filaments (Collette and Klein-MacPhee 2002). This pattern fits the available information on spawning time in the southern Gulf of St. Lawrence (June: Needler 1940), in the Annapolis River (late June to early July: Jessop 1983), and the vicinity of Saint John Harbour (early June: Doyle *et al.* 2011). Hence, if this interpretation is correct, sampling in nearby marsh creeks and tidal channels in June may yield mature *M. menidia* in the process of spawning.

The four remaining dominant fishes collected in our study belong to the Gasterosteidae. *Gasterosteus aculeatus* and *G. wheatlandi* are the dominant stickleback species in the marine portions of estuaries in southern Labrador (Wroblewski *et al.* 2007), eastern Newfoundland (Methven *et al.* 2001), southern Gulf of St. Lawrence (Robinson *et al.* 2001; Joseph *et al.* 2006), and the Bay of Fundy (Arens 2007). These species also continue to be prominent members of the Gasterosteidae off northern New England, although *A. quadracus* and *P. pungitius* can also be abundant (Targett and McCleave 1974; Ayvazian *et al.* 1992; Lazzari *et al.* 1999). In our study, *G. aculeatus* and *G. wheatlandi* shared similar spatial and temporal distributions and were most abundant at downstream sites in spring during spawning (Scott and Crossman 1973) when temperature (mean 14.7°C) and salinity (12.1 ppt) were lowest. Catches of both species decreased throughout summer and were lowest in fall, possibly due to migration out of the estuary later in summer (Hanson and Courtenay 1995; Able and Fahay 2010). Judging by their silvery body colour and occasional very high catches, it appears that *G. aculeatus* and *G. wheatlandi* are more pelagic and schooling than either *A. quadracus* or *P. pungitius* which lacked silver body pigment and were typically taken in lower numbers, especially at higher-salinity lagoon sites. Catches of *A. quadracus* and *P. pungitius* increased from spring to fall, a pattern opposite that for *G. aculateus* and *G. wheatlandi*. The abundance of *P. pungitius* at upstream sites is consistent with its tolerance of high concentrations of suspended sediments (Chiasson 1993).

This study has established baseline data for seven fish species and environmental conditions in the three largest estuaries of Kouchibouguac National Park. Regular monitoring of estuarine habitats is necessary to detect changes in fish assemblages in response to disturbance; however, meaningful assessment requires comparison with a baseline of natural variations across seasons. Additional sampling at new sites using different methods would determine the extent of migration and help explain seasonal fluctuations in abundance.

Acknowledgements

We thank Greg Klassen for his knowledgeable input, for initiating the study, and for his constructive criticism during the study. Eric Tremblay, park ecologist of Kouchibouguac National Park, provided the means and opportunity to conduct the fieldwork. We thank the many technicians who assisted with laboratory and fieldwork. We thank Donald McAlpine for accepting our voucher specimens for curation at the New Brunswick Museum in Saint John. The project was partly funded by Parks Canada; the Biology Department and the School of Graduate Studies, University of New Brunswick Saint John; and the New Brunswick Museum.

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Received 11 February 2014
Accepted 10 February 2015

Life History and Distribution of the Arctic Pseudoscorpion, *Wyochernes asiaticus* (Chernetidae)

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Buddle, Christopher M. 2015. Life history and distribution of the Arctic pseudoscorpion, *Wyochernes asiaticus* (Chernetidae). Canadian Field-Naturalist 129(2): 134–138.

The Pseudoscorpiones are a remarkable yet understudied order of arachnids. The northernmost species in North America, *Wyochernes asiaticus* (family Chernetidae), occurs under rocks beside rivers or creeks and can be found above the Arctic Circle in Canada. In North America, the species is limited to the northwest, although its global distribution includes parts of Asia. It is presumably a Beringian species with quite specialized habitat affinities. I report on some life history traits of this species, based on examination of nearly 600 specimens from 16 localities in the Yukon and Northwest Territories. All life stages were collected. Of the females, 17% were carrying brood sacs, with an average of 10.5 eggs per brood sac; larger females tended to have larger clutch sizes. Despite these data on the natural history and distribution of *W. asiaticus*, its phylogeographic history and how the species feeds, disperses, and recolonizes habitats after flooding remain largely unknown.

Key Words: *Wyochernes asiaticus*; Arachnida; natural history; biogeography; Pseudoscorpiones; Yukon Territory; Northwest Territory; Arctic

Introduction

According to Tschinkel and Wilson (2014: 442), "the story of any species chosen at random is an epic, filled with mysteries and surprises that will engage biologists for generations to come." In that essay, the authors argue for the value of knowing the natural history of species and how that knowledge is fundamental to progress in biology. Tewksbury *et al.* (2014) support this view and also argue that science and society's well-being is dependent on knowledge about natural history. That said, discovering, observing, and collecting data about "basic" life history is far from easy and seldom funded by major research grants. Furthermore, life-history data for arthropods are scarce in part because of their overwhelming diversity and relatively few specialists. This is apparent for the "neglected cousins" within the Arachnida (Harvey 2002), including the relatively small order Pseudoscorpiones.

There are over 3000 known Pseudoscorpiones species (Harvey 2002), but searching the literature for published accounts of their natural history and biology yields relatively few citations, and most describe tropical species (e.g., Zeh and Zeh 1992). One North American exception is the detailed account of *Microbisum confusum* by Nelson (1982), in which he counts, describes, and measures thousands of specimens and provides insights into the phenology and life history of the species. A text by Legg and Jones (1988) is also notable: this gem of a book lists the distribution and natural history of pseudoscorpions occurring in the United Kingdom. This information is far ahead of that for pseudoscorpions in any other region of the world.

Looking to northern North America, Canada is probably home to over 30 species of pseudoscorpions (Buddle 2010), but only a few species reach the northern boreal zone and beyond. *Microbisium brunneum* is a clear exception, as it has been recorded from sphagnum moss in relatively northern locations (Koponen and Sharkey 1988). In 1990, V. Behan-Pelletier collected a pseudoscorpion just north of the Arctic Circle (at 66.80°N, at Sheep Creek in the Yukon†), and Muchmore (1990) described the species as *Wyochernes arcticus*, new to science. Based on comparisons with Old World specimens, Muchmore (1996) later concluded that *W. arcticus* was the same as *W. asiaticus* (Redikorzev, 1922), which is found throughout central Asia through to Siberia. The type locality of *W. asiaticus* is in Tibet.

As part of other ongoing Arctic research (e.g., Bowden and Buddle 2012), I visited Sheep Creek in 2008 and found additional specimens of *W. asiaticus*. True to the description provided by Muchmore (1990), flipping rocks at the river's edge revealed dozens of specimens. Return trips to the Yukon in later years allowed for the collection of additional specimens from more localities in the Yukon and Northwest Territories.

Wyochernes asiaticus is a charming arachnid (Figure 1), occupying extreme environments in unusual habitats. The river beds where the species exists flood seasonally and are extremely remote. To my knowledge,

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†The published locality (Muchmore 1990), 69.17°N, 140.30°W, is incorrect based on personal communication with the collector, V. Behan-Pelletier (March 2014); the actual location on the 1984 collections was approximately 66.80°N, 136.32°W, where the Dempster Highway crosses Sheep Creek, just north of the Arctic Circle.

FIGURE 1. Female pseudoscorpion, *Wyochernes asiaticus* (Chernetidae), showing a brood sac. Body length is approximately 2 mm. Photo: Crystal Ernst.

this species is the most northern member of this arachnid order in North America. The objective of this research was to collect life-history data for *W. asiaticus* along the Dempster Highway, which stretches from near Dawson City Yukon, north to Inuvik, Northwest Territories. I wanted to address the following questions: Where is *W. asiaticus* found? What are the sizes of the various life stages? Do larger females have larger clutch sizes? Does its size or fecundity vary along a latitudinal gradient in northwest North America? This work will hopefully open doors to more questions and contribute baseline data for these understudied and underappreciated arachnids.

Methods

Between 2008 and 2012, *W. asiaticus* was collected from under rocks near creeks and rivers at 16 locations along the Dempster Highway, from 64.28° to 67.18°N and 135.75° to 138.49°W (Figure 2). At each location, field teams (see acknowledgements) flipped rocks collected any and all life stages of *W. asiaticus* found underneath. The searches were between 30 minutes and 2 hours in duration, and we aimed for between 10 and 20 specimens. This variation was due to various issues that stopped us from collecting additional specimens (e.g., inclement weather, biting flies). Field teams also searched (unsuccessfully) for pseudoscorpions besides creeks from between approximately 64.0°N to 64.3°N along the Dempster Highway, and beside creeks and rivers between Whitehorse (Yukon) and Dawson City (Yukon). To the north, no other suitable habitats were found further north than 67.18°N.

Specimens were preserved in 70–90% ethanol and transported to the laboratory, where they were counted and measured using an SMZ 1500 dissecting microscope (Nikon Instruments, Inc., Melville, New York, USA), fitted with an ocular micrometer. Body length and carapace length were measured for all specimens. If females were carrying brood sacs (i.e., with individual eggs), the clutch size was determined.

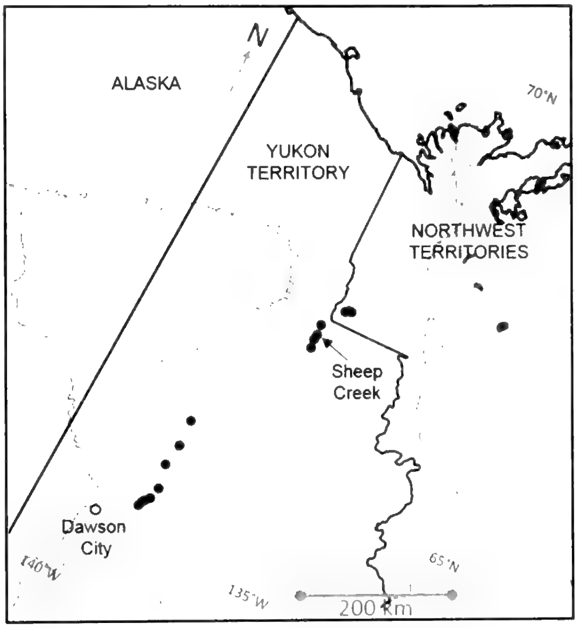

FIGURE 2. Collection localities (solid circles) of the pseudoscorpion, *Wyochernes asiaticus* (Chernetidae), in the Yukon and the Northwest Territories, Canada. Map created with SimpleMappr, http://www.simplemappr.net.

Data were analyzed using descriptive statistics. Correlations between size and latitude and between female size and fecundity were tested for significance. All specimens were deposited in the Lyman Entomological Museum (McGill University, Ste-Anne-de-Bellevue, Quebec, Canada).

Results and Discussion

Wyochernes asiaticus (Figure 2) was readily found at collection sites in the Yukon and Northwest Territories. The specimens found at an unnamed creek at 67.18°N and 135.75°W represent the northernmost record for the species in North America, expanding its northern range by approximately 50 km (straight-line distance) from that established by V. Behan-Pelletier in the 1980s (Muchmore 1990). The habitat for *W. asiaticus* was always the same: individuals at all life stages were found under rocks beside rivers or creeks. Many rocks harboured no individuals, some revealed a few, and fewer rocks hid dozens of specimens (see video at https://www.youtube.com/watch?v=O_KISY4Zz_Y which depicts pseudoscorpion activity on the underside of a rock).

These arachnids seem to have a preferred "zone" beside creeks or rivers in areas that probably flood annually (i.e., during spring melt). In general, they were not found directly (i.e., 1-2 m) adjacent to flowing water, nor were they found in areas that appeared to flood only infrequently (i.e. higher up on banks, in regions where there was some soil development and permanent vegetation). There were found between these two regions, in habitats characterized as being well-drained, full of rocks, and a distinct lack of soil or permanent vegetation. This raises a curious question: what happens to *W. asiaticus* during times when the rivers flood? They may be swept away, hang on under rocks as water runs over them, retreat to their silken chambers, or move to higher ground. It would be most interesting to understand this aspect of their life history, but additional fieldwork would be required to do so.

Despite efforts to find *W. asiaticus* under rocks in riparian zones further south than 64.38°N, these searches turned up nothing. We, therefore, assume that there is a limit to the southern distribution of this species. I suspect the species can be found further north; however, our northernmost collection site was at the last accessible river with rocks and stones along its banks. I was able to collect the species near the headwaters of small streams heading up to mountain passes, e.g., from the car park at Windy Pass, near 65.06°N, 138.26°W (Figure 2). At this location, specimens were still found when the stream was only a trickle and less than 1 m wide. Although *W. asiaticus* can crawl, they do not move very quickly, which suggests that these arachnids have other means of reaching remote habitats. Phoresy (the act of "hitchhiking" on another species) is well known in pseudoscorpions and is particularly common in the Chernetidae (see, for example, Muchmore 1971). I suspect that *W. asiaticus* rides on other animals to disperse to new habitats along headwater streams or to recolonize habitats. The transporting species for this phoresy is unknown.

From a broader biogeographic perspective, I have seen specimens of *W. asiaticus* from central Alaska (courtesy of D. Sikes, University of Alaska, Fairbanks), and the species is known from several localities in Asia. In North America, its occurrence along the Dempster Highway strongly suggests that it is a Beringian species, minimally occupying what were mainly unglaciated regions of northwest North America during the last glacial maximum. Along with a suite of other interesting species, such as the holarctic Root Vole (*Microtus oeconomus*) (Brunhoff *et al.* 2003), North American *W. asiaticus* is truly a relict of the past, and occupies a unique habitat in a fascinating biogeographic region of the globe. Follow-up studies, using population genetics, would be extremely valuable in answering broader phylogeographic questions about the species. Unlike other groups that radiated from this unglaciated region (e.g., *Polyommatus* butterflies [Vila *et al.* 2011]), *W. asiaticus* appears to have remained relatively limited in its distribution in North America.

A total of 573 individual pseudoscorpions were collected and measured (Figure 3). The various life stages were easily recognized. Females predominated, possibly because their relatively large size and the presence, in some, of yellow brood sacs made them easier to find (Figure 1). Forty-eight of the 281 females had brood sacs, and the average (± standard error) clutch size was 10.5 ± 0.4 eggs/female (with a range of 5–15 eggs per brood). These measures of fecundity are aligned with some of the general estimates given by Weygoldt (1969). Although there was much variation, larger females, measured as carapace length or full body length, tended to have more eggs within their brood sac (Figure 4). This was expected, as other arachnids (e.g., spiders) show a similar pattern (e.g.,

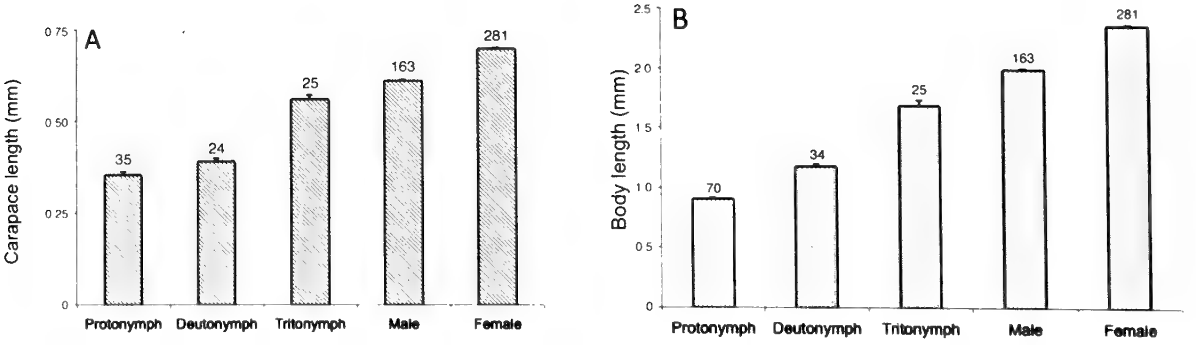

FIGURE 3. Average carapace (A) and body length (B) (+ standard error) of the pseudoscorpion, *Wyochernes asiaticus* (Chernetidae), by life stage: protonymph, deutonymph, tritonymph, and adult male and female. The number of specimens is indicated above each bar. The discrepancies in sample sizes of protonymphs and deutonymphs are a result of some specimens being too small to measure carapace length accurately.

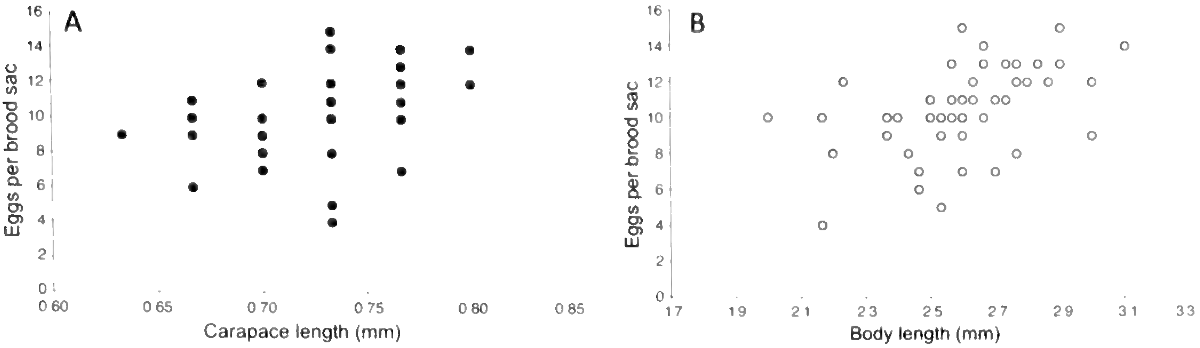

FIGURE 4. Number of eggs in brood sac of female pseudoscorpions, *Wyochernes asiaticus* (Chernetidae), as a function of carapace length (A, $r = 0.40$), and body length (B, $r = 0.47$). Symbols represent individual pseudoscorpions: Forty-eight females were used for both graphs, but some overlapping sizes occurred, hence the fewer symbols in (A).

Bowden and Buddle 2012) and also display high variation in this relation. It would be interesting to look more deeply into the relation between resource limitation and clutch size. Despite the time spent in the field and the collection of almost 600 individual *W. asiaticus*, its prey and feeding behaviour have yet to be observed.

All collections were made in July, and it is possible that collecting *W. asiaticus* at other times during the summer would yield different proportions of the life stages. Moulting likely occurs at times other than July, as specimens were not found in silken retreats. However, as all life stages were frequently found, these arachnids may take more than 1 year to reach maturity, and perhaps the adults are relatively long lived, a common feature of other Arctic arthropods (e.g., Danks 2004). There was no relation between latitude (as a proxy for temperature) and body size (data not shown), and thus there was no support for Bergmann's Rule (or the converse, which may better apply to ectotherms [see Mousseau 1997]), which predicts a size–latitude relation. As Shelomi (2012) argues, patterns of body size in relation to latitude, for arthropods, are largely idiosyncratic.

Conclusions

Although pseudoscorpions have been largely neglected, these findings may inspire more work on the natural history and biology of these fascinating arachnids. Despite significant collection efforts over many years, hours at the microscope, and hundreds of specimens, more questions have been raised by our work than have been answered. We now know that *W. asiaticus* is common in parts of northwest North America, likely as a relict that survived the last glaciation, and it can be found easily under rocks next to rivers and creeks, including small creeks in mountainous regions. All life stages can be collected and measured, and some benchmark measurements of clutch size are now available. Future research on the phylogeography, short-distance dispersal, and feeding behaviour of *W. asiaticus* would be most interesting. In conclusion, observing these marvelous animals in one of the most beautiful areas of the planet, was gratifying, awe-inspiring, and helped solidify a love of natural history. What has been learned is only the prologue to a truly astounding epic: many more discoveries await.

Acknowledgements

Many, many people helped collect specimens, including J.-F. Aublet, J. Bowden, W. O. Buddle, D. Currie, C. Ernst, B. Sharanowski, K. Sim, and L. Timms. Thanks to Y. Wang for measuring specimens. We thank the Yukon Territorial Government and the Northwest Territorial Government for research permits. Funding from the Natural Science and Engineering Research Council of Canada and the Northern Scientific Training Program helped make this work possible.

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Received 1 April 2014
Accepted 8 October 2014

The Canada Lynx (*Lynx canadensis*) of Isle Royale: Over-harvest, Climate Change, and the Extirpation of an Island Population

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Licht, Daniel S., Ron A. Moen, D. Paul Brown, Mark C. Romanski, and Robert A. Gitzen. 2015. The Canada Lynx (*Lynx canadensis*) of Isle Royale: over-harvest, climate change, and the extirpation of an island population. Canadian Field-Naturalist 129(2): 139–151.

In the 1930s, the Canada Lynx (*Lynx canadensis*) was extirpated from Isle Royale, a 535-km^2 island located in western Lake Superior, 22 km from the Ontario and Minnesota shorelines. The first half of the 20th century was a time of change on Isle Royale as Caribou (*Rangifer tarandus*) disappeared, Coyotes (*Canis latrans*) briefly appeared, Moose (*Alces americanus*), Grey Wolves (*Canis lupus*), and Red Foxes (*Vulpes vulpes*) became established, and the habitat was altered by fire, logging, and over-browsing. Although these changes may have contributed to the demise of the Canada Lynx, our results suggest that over-harvest was a primary cause. Assuming a peak carrying capacity of 75 Canada Lynx and harvest rates comparable to those reported from 1890–1935, a population viability analysis indicated that the island population had a 0% chance of surviving 50 years. The analysis also indicated that, even in the absence of harvest, the population had only a 14% chance of persistence for 250 years. However, when 10 Canada Lynx were added to the modeled population every 10th year, the probability of persistence increased to 100%. Our analyses suggest that the island's Canada Lynx population maintained itself by periodic immigration across an ice bridge; therefore, natural recolonization should be possible. However, the probability of ice-bridge formation has declined from 0.8 in the winter of 1958–59 to 0.1 in 2012–13, likely as a result of climate change. The Isle Royale situation exemplifies another impact of climate change and the possible need to augment populations to mitigate the loss of connectivity.

Key Words: Canada Lynx; *Lynx canadensis*; climate change; connectivity; island biogeography; Isle Royale; metapopulation; over-harvest; population viability analysis

Introduction

The historical range of the Canada Lynx (*Lynx canadensis*) includes Alaska, Canada, and, within the conterminous United States, parts of New England, the upper Midwest, and the Rocky Mountains (McKelvey 2000; Anderson and Lovallo 2003; Poole 2003). In recent times, the distribution of the Canada Lynx has been reduced in the southern portion of its range (Laliberte and Ripple 2004; Koen *et al.* 2014), mainly due to a combination of over-harvest, loss of suitable habitat, and changes in faunal communities (Ruggiero and McKelvey 2000; United States Fish and Wildlife Service 2000; Anderson and Lovallo 2003). The species is now listed as "threatened" in the conterminous United States under the U.S. Endangered Species Act (Ruggiero and McKelvey 2000; United States Fish and Wildlife Service 2000; Interagency Lynx Biology Team 2013). In Canada, the species is listed as regionally endangered in Nova Scotia and New Brunswick (Mackinnon and Kennedy 2008).

Canada Lynx were present and seemingly abundant on Isle Royale when Europeans explored the island in 1857 (Palliser 1863). Large-scale lynx trapping on Isle Royale apparently started in the 1890s (Martin 1988). Historical records suggest that there was a resident population of Canada Lynx on Isle Royale until about the 1930s (Adams 1909; Mech 1966; Johnsson *et al.* 1982; Martin 1988). Although there have been a few reports of lynx on Isle Royale since then (Johnsson *et al.* 1982; Martin 1988; Cochrane 1996), there is no evidence of an established breeding population. The island and surrounding islets and waters now constitute Isle Royale National Park, which is managed by the U.S. National Park Service (NPS 1998), whose policies call for restoring extirpated native species when feasible (NPS 2006). A critical step in assessing the feasibility of reintroduction is to determine the cause(s) of the species' extirpation. We reviewed the history of the Canada Lynx on Isle Royale and evaluated possible reasons for extirpation of the species.

Study Area

Isle Royale is a 535-km^2 island (about 72 km × 14 km) in western Lake Superior, about 22 km from the Ontario and Minnesota shorelines (Figure 1). It is surrounded by about 400 islets. The island is characterized by short cool summers and long cold winters. Mid-winter snow depths average 44 cm (Vucetich and Peterson 2011).

Before European settlement, Isle Royale supported an old-growth boreal ecosystem (Cooper 1913; Cole

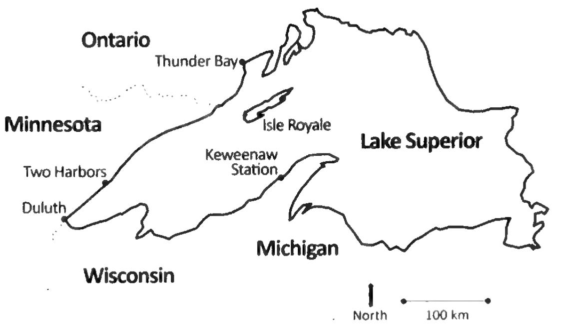

FIGURE 1. Location of Isle Royale.

et al. 1997), with Canada Lynx and Caribou (*Rangifer tarandus*) as the largest resident wildlife (Adams 1909; Martin 1988; Cochrane 1996). Indigenous people periodically occupied the island for the purposes of hunting, fishing, and copper mining (Shelton 1997). Settlement by people of European descent occurred from the early part of the 19th century to the first half of the 20th century, primarily for the purposes of fishing and copper mining. Fur trapping, mainly American Beaver (*Castor canadensis*), by European settlers apparently started in the early 19th century (Cochrane 2013), although there is at least one oral history account of a Canada Lynx being trapped in 1873–74 (Cochrane 1996). Significant changes to the island ecosystem occurred in the early 20th century as a result of logging, a large and severe forest fire, and over-browsing by Moose (*Alces americanus*), which colonized the island in 1900–10 (Murie 1934; Mech 1966). In 1940, Isle Royale National Park was established, and hunting and trapping were prohibited.

The island is currently dominated by a mix of Balsam Fir (*Abies balsamea* (L.) Miller)–White Spruce (*Picea glauca* (Moench) Voss)–Trembling Aspen (*Populus tremuloides* Michaux) and Eastern White Cedar (*Thuja occidentalis* L.)–Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh)–Tamarack (*Larix laricina* (Du Roi) K. Koch)–Black Ash (*Fraxinus nigra* Marshall) vegetation types (The Nature Conservancy 1999). The island is recognized for the Grey Wolf (*Canis lupus*) and Moose populations it supports and the long-term research on their ecology (Wolf–Moose Project 2013*). The park is designated as an International Biosphere Reserve and 99% of the island is managed as wilderness under the U.S. Wilderness Act of 1964, which prohibits motorized equipment. There are no permanent human residents and negligible infrastructure.

Canada Lynx are no longer present on Isle Royale. The limited evidence suggests they had a long history of occupation before their extirpation. Cleland (1968) found lynx bone fragments at archeological sites dating back about 2000 years and referred to sites with lynx remains dating back about 600 years (Cleland 1966). In recounting his 1857 visit to Isle Royale, Palliser wrote "the lynx is the largest animal on the island, and is said to be very common" (Palliser 1863: 23). William P. Scott, an early resident of the island, noted the presence of lynx around 1890 (Scott 1925). Martin (1988: 29) wrote that "commercial exploitation of lynxes was underway on the island by 1897." Martin (1988) reported that juvenile lynx were harvested on the island, indicating reproduction and an established population.

A University of Michigan biological study conducted in 1904–05 reported lynx as present, apparently abundant, and distributed over much of the island (Adams 1909). The study also reported that "with the possible exception of the White-footed Mouse (*Peromyscus leucopus*), the Hare (*Lepus americanus*) is the most abundant mammal upon Isle Royale" (Adams 1909: 410) and that Red Squirrels (*Tamiasciurus hudsonicus*) "were exceedingly abundant" (Adams 1909: 399), suggesting high-quality habitat for lynx. Based on these reports, we assume that lynx occupied Isle Royale in pre-Columbian times and were abundant at the time of European settlement. However, sometime in the 1930s they were extirpated from the island (Mech 1966; Johnsson *et al.* 1982; Martin 1988).

Methods

We reviewed the scientific and historic literature to identify possible causes for the lynx extirpation. We identified four causes that we critiqued using an inductive qualitative approach; disease, habitat changes, interactions with other predators, and cycles in prey populations. We searched extensively in the peer-reviewed literature for evidence that would support extirpation of Canada Lynx on Isle Royale by each of these possible causes. We summarized results of the literature search qualitatively, and concluded whether there was or was not support for being the cause of extirpation.

Two other potential causes, over-harvest and changes in connectivity, were analyzed quantitatively. Over-harvest was analyzed with a population viability analysis, while changes in connectivity between Isle Royale and the mainland were analyzed by searching for evidence of an ice bridge being formed in each winter that data was available.

To better understand the role that harvest played in the extirpation of the Isle Royale lynx population, we conducted a population viability analysis using VORTEX 9.99 (Lacy and Pollak 2014). We used published vital rates (see Anderson and Lovallo 2003; Steury and Murray 2004; Moen *et al.* 2008), unpublished data from studies in Minnesota (R. Moen, unpublished data), and professional judgement to establish input parameters (Table 1). We conducted sensitivity testing to evaluate and refine model inputs, to identify influential parameters, and to assess the reasonableness of the model (Lacy and Pollak 2014). VORTEX models inbreeding depression using the concept of lethal equivalents whereby 1) new individuals are killed if they have two copies of the same lethal allele, and 2) survival is re-

TABLE 1. Input parameters used in population viability analysis of Canada Lynx (*Lynx canadensis*) on Isle Royale. Values following the ± symbol are the amount of variability at the peak and nadir of the cyclical scenarios.

Breeding	
Adult females breeding at low density	90% (SD 5)
Adult females breeding at carrying capacity	50% (SD 5)
Mean no. of mates/successful sire	1.5
Inbreeding depression	
Lethal equivalents	3.14
Proportion due to recessive lethal	50%
Reproduction	
Age at first offspring, females and males	2 years
Maximum age of reproduction	10 years
Maximum no. litters/year	1
Maximum no. young/litter	6
Mean no. young/litter	3.3 ± 1 (SD 0.9)
Sex ratio of young	50:50
Environmental variation concordance of reproduction and survival	Yes
Annual mortality rate, both sexes	
Kitten (age 0–1 year)	45% ± 20 (SD 10)
Yearling (age 1–2 years)	45% ± 20 (SD 10)
Adult	10% ± 5 (SD 5)
Catastrophes	0
Carrying capacity	75 (SD 10)
Starting population	Stable age distribution

Note: SD = standard deviation.

duced as the inbreeding coefficient increases (Miller and Lacy 2005; Lacy *et al.* 2014; Lacy and Pollak 2014). We used the VORTEX version 9.99 default default value of 3.14; however, we also ran scenarios assuming no inbreeding depression to better understand the influence of inbreeding on model outputs. We modeled allele frequencies using a single neutral locus and unique alleles for each founder (Lacy *et al.* 2014). For harvest simulations we ran 1000 iterations for 50 years, i.e., the approximate time frame of the reported lynx harvest at the island. For non-harvest simulations, we initially used 1000 years, but ultimately used 250 years as that period best illustrated the impacts of the various assumptions.

Canada Lynx and their primary prey, Snowshoe Hare, are known to go through an 8–11-year population cycle (Hodges 2000a; Krebs *et al.* 2001: Figure 2). Historical reports from 1900 to the 1930s suggest that the Isle Royale hare population was cyclical (Martin 1988; Allen 1994) as does more recent fieldwork (Vucetich and Peterson 2011). Therefore, we assumed a cyclical lynx population. We used a 10-year sinusoidal function to mimic the cycle. We varied lynx mortality, litter size, and percentage of females breeding to

FIGURE 2. Hudson's Bay Company yearly lynx fur returns for the Lakes region (southern Ontario and western Quebec), 1901–39. Source: Elton and Nicholson (1942).

account for changes between the cycle nadir and peak (Table 1). Our closed cyclical model for Isle Royale resulted in a four-fold increase in lynx abundance from nadir to peak. Our cyclic variability was modest compared with that found in northern regions (Poole 1994; Slough and Mowat 1996); however, amplitudes are believed to be smaller in southern ranges (Hodges 2000b). For example, Slough and Mowat (1996) showed a nine-fold change in Snowshoe Hare abundance over a cycle in the Yukon Territory, whereas Vucetich and Peterson (2011) showed only a three- to four-fold change in an index of hare abundance at Isle Royale. There is some evidence that lynx populations in the southern portion of the species range may even be non-cyclical (Hodges 2000b; Murray *et al.* 2008); however, that may be a recent phenomenon (Poole 2003). Nevertheless, we also ran non-cyclical simulations.

An influential input parameter was carrying capacity. Estimates of Canada Lynx densities in Minnesota and Ontario, and Snowshoe Hare pellet surveys on Isle Royale, suggest that the current peak carrying capacity of the island may be 30–40 lynx (Licht *et al.* in prep). However, historical lynx harvests at Isle Royale suggest a population substantially greater than that, at least for brief periods, as evidenced by a minimum of 48 lynx harvested in the winter of 1903–04 and 67 in the winter of 1916–17 (Adams 1909; Foster 1917; Mech 1966; Martin 1988). Poole (2003) reviewed the scientific literature and suggested that lynx populations in mature forests in the more southern ranges had peak densities ranging from 8 to 20 per 100 km^2: extrapolating from the mid-point gives a population of 75 lynx for Isle Royale. This peak abundance is plausible based on historical harvests. Therefore, we set carrying capacity at 75 lynx in our baseline model. We also ran simulations with carrying capacities of 38 and 113 lynx; the former approximates the current estimated non-cyclical carrying capacity (D. S. Licht, unpublished data) and the latter approximates the high end reported by Poole (2003).

The historical record from Isle Royale includes harvests of 48 lynx in the winter of 1903-04, 67 lynx in the winter of 1916-17, and over 25 lynx in the early 1930s (Adams 1909; Foster 1917; Mech 1966; Martin 1988). These are likely minimum harvests. For example, the report of 48 lynx captured in 1903-04 was by a father-son combination and primarily from a small portion of the island (Adams 1909). Additional reports of harvests and trapping effort in the 1890-1930s are documented by Martin (1988), Mech (1966), and Cochrane (1996), but little additional quantitative information is available. Cumulatively, the reported harvests appear to have the potential to have extirpated the Isle Royale lynx population. The peak historical harvests in 1903–04 and 1916–17 are 13 years apart with the reported harvest in the early 1930s approximately 14–19 years later (Adams 1909; Foster 1917; Mech 1966; Martin 1988). This periodicity does not synchronize with the reported 8–11 year lynx population cycle nor do the reported historical harvests align perfectly with the lynx population peaks for the Lakes region as reported by Elton and Nicholson (1942: Figure 2), creating a conundrum if one assumes the reported large harvests were at population peaks. One possible explanation is that the timing of the population peaks at Isle Royale may have differed from the regional peaks reported by Elton and Nicholson (1942), as lynx population peaks are not synchronous across the species' range (Ranta *et al.* 1997; Stenseth *et al.* 1999). Another plausible explanation is that reported harvests did not occur in years when the lynx population peaked. Anderson and Lovallo (2003) stated that lynx harvest rates may be somewhat independent of lynx density and driven more by pelt prices. Furthermore, in a small area, such as Isle Royale, the addition of just a few trappers or trap lines could cause a substantial change in trapping effort, thereby influencing harvest rates more than lynx density. As a result of these unknowns, we ran simulations where harvest peaks and lynx population peaks were asynchronous and other scenarios where harvest and population peaks coincided by assuming a 13-year lynx cycle. We ran simulations that modeled the reported harvests of 48, 67, and more than 25 lynx; simulations that also included 5 or 10 additional lynx harvested each year to account for unreported harvests; and simulations where we removed 50 lynx every 13th year as well as an additional 5 or 10 lynx in the interim years. We did not find useful information regarding the demographic composition of the lynx harvested at Isle Royale; however, others have reported that adult males typically comprise the majority of lynx harvests (Bailey *et al.* 1986; Quinn and Thompson 1987; Poole 1991). For all harvests, we assumed a composition of 60% adult male, 30% adult female, and 10% kittens split equally between the sexes.

Our initial simulations assumed a closed population. We subsequently posited that lynx might have historically immigrated to Isle Royale every 10 years or so coincident with lynx population peaks farther north. Therefore, we ran simulations that assumed supplementation every 10th year. We altered the default sequence of events in VORTEX so that supplementation (i.e., immigration) occurred before harvest. Carrying-capacity truncation occurred after those events. Henderson (1978) reported about a 12-fold nadir-to-peak increase in lynx harvests in Minnesota from 1940 to the 1970s and Gunderson (1978) reported an eight-fold and two-fold increase in harvested lynx from two sites in Ontario from 1955–58 to 1960–63. We assumed immigration of 10 or 20 adult lynx every 10th year, coinciding with peaks in the resident population: the combination of supplementations and growth of the resident population generally resulted in a five-fold increase from nadir to peak. Although lynx irruptions in Canada sometimes plateau over multiple years (Gunderson 1978), we assumed a single-year influx of immigrants as that approximates what was observed in Minnesota (Mech 1973; Henderson 1978). We assumed a 50:50 sex ratio of the immigrants as reported by Mech (1980) for a recently colonized site in Minnesota. When comparing supplementation and non-supplementation simulations, we allowed lynx immigration to occur only if there was an extant population at the time of augmentation.

Although lynx can swim and are known to cross cold rivers (Feierabend and Kielland 2014), the farthest distance we know of a lynx swimming is 3.2 km (Kobalenko 1997); hence, we viewed it as unlikely that immigration occurred via swimming. We thought it more plausible that historical lynx immigration to Isle Royale occurred via an ice bridge between the mainland and the island. In that case, lynx could have recolonized Isle Royale following extirpation, as lynx populations in Minnesota and Ontario have recovered from early-20th-century lows (Poole 2003; Moen *et al.* 2008). Furthermore, lynx invasions from Ontario into Minnesota have been documented since the 1960s (Mech 1973; Gunderson 1978; Henderson 1978). However, we speculated that a decline in ice-bridge formation in recent decades may have prevented lynx recolonization of Isle Royale. We used three datasets to evaluate a possible decline in ice-bridge formation between the mainland and Isle Royale.

We used National Oceanic and Atmospheric Administration (NOAA), Great Lakes Environmental Research Laboratory ice atlases (Assel *et al.* 2002; NOAA Great Lakes Environmental Research Laboratory 2014) to calculate the number of days each winter during 1973–2011 that an ice bridge formed between Isle Royale and the mainland. The ice concentration class with the greatest ice surface area and, therefore, the most potential for crossing by lynx, was the ≥ 90% class. We looked at each daily image and summed the number of days each winter with ice of class ≥ 90% connecting the mainland to the island. We ran a linear regression of the sum of the days against year. The strength of the dataset is that the data were somewhat systematically collected and the dataset allowed the summation of the total number of days an ice bridge formed each winter. Its weakness is that the iciest class could have as little as 90% ice cover which may not be enough for a lynx to traverse from the mainland to the island.

Our second analysis of ice-bridge formation used statements from 1965–66 to 2012–13 Isle Royale Wolf–Moose Project annual reports (Wolf–Moose Project 2013*). Additional data for 1958–59 to 1964–65 and clarification of some ambiguous statements in the annual reports were provided by R. Peterson (personal communication, 2014). For each winter 1958–59 to 2012–13, we assigned either "yes" or "no" for ice-bridge formation. We then ran a logistic regression on the binomial data. The strength of this dataset is that it better captured true ice-bridge formation that could be traversed by an animal as the primary reason the investigators recorded the observations was for documenting the potential for wolf movement between the mainland and the island. Its weakness is that the total number of days each winter with an ice bridge was not captured, and investigators were only on the island during a portion of the winter (Wolf–Moose Project 2013*).

Our final ice-bridge analysis used 1900–1970 ice-thickness data collected by the National Weather Service (Assel 2004). We evaluated datasets from the Duluth Harbor, Two Harbors, and Keweenaw Waterway stations (Figure 1); these stations had data for 66, 44, and 54 of the years, respectively. We used the annual mean or midpoint of the reported range for each station and regressed that against year. The value of the datasets is that they covered 1900–1970, a period not covered by the other datasets and a time when lynx still occupied Isle Royale. Their weakness is that the data were not collected systematically, the parameter was near-shore ice thickness which might not be strongly correlated to ice surface coverage on the lake, and the stations were a substantial distance from Isle Royale (245 km in the case of Duluth Harbor station).

Results

Qualitative evaluation of possible reasons for the extirpation of Canada Lynx

Disease: Disease can have a catastrophic impact on wildlife, especially small isolated populations (de Castro and Bolker 2005; Cully *et al.* 2010; Descamps *et al.* 2012). The anthropogenic introduction of canine parvovirus to Isle Royale in 1981 was probably a factor in a crash of the island's wolf population (Peterson *et al.* 1998). Therefore, we evaluated disease as a possible cause of the lynx extirpation.

Lynx are susceptible to a variety of diseases, some of which can be lethal (Anderson and Lovallo 2003). Wild *et al.* (2006) documented Canada Lynx mortality from plague (*Yersinia pestis*) in Colorado; however, that disease is not known to occur in the Isle Royale region. Ryser-Degiorgis *et al.* (2005) reported that sarcoptic mange (*Sarcoptes scabiei*) is the most common infectious cause of death in free-ranging Eurasian Lynx (*Lynx lynx*), but mange is not known to have occurred at Isle Royale. Vashon *et al.* (2012) reported lungworm in Canada Lynx in Maine, but only one of 65 animals in that study was reported to have died from disease. In a sample of 215 Canada Lynx, Biek *et al.* (2002) found a low prevalence of a suite of pathogens. Moen *et al.* (2008) did not find disease to be a significant mortality factor for Canada Lynx in nearby Minnesota. Likewise, *Canada Lynx Conservation and Assessment* (Interagency Lynx Biology Team 2013) does not list disease as a high concern in lynx conservation. We know of no evidence of diseased-caused mortality of Canada Lynx on Isle Royale.

Systemic transitional changes in the vegetation community: The vegetation community on Isle Royale has changed dramatically in the past century due primarily to logging, fire, and Moose overabundance (Murie 1934; Mech 1966; Snyder and Janke 1976). Logging and fire can significantly alter habitat; however, depending on the spatial pattern, severity, and return intervals, these disturbances could increase the abundance of lynx by improving conditions for Snowshoe Hare (Parker *et al.* 1983; Moen *et al.* 2008; Interagency Lynx Biology Team 2013). At an Ontario study site with 27% disturbance due to fire, logging, and insect damage, Quinn and Thompson (1987) found that several lynx population parameters were as good as or higher than they were at a site with only 17% disturbance.

On Isle Royale, over-browsing by Moose might have degraded habitat for Snowshoe Hare. Moose apparently arrived on the island between 1900 and 1910 (Cochrane 2013). The population reached several thousand in the early 1930s, but then starvation caused a population crash in 1933–35 (Krefting 1974). Murie (1934) reported that Snowshoe Hares were scarce in 1930, and Mech (1966) cited island residents who reported seeing fewer hares in the late 1920s and early 1930s than they had in earlier years; whether these changes were due to systemic habitat alteration or natural oscillations in hare populations is not known. Allen (1994) suggested that Moose overabundance on the island resulted in a decline in Snowshoe Hare numbers that may have contributed to the extirpation of lynx. Conversely, some researchers have reported that forage competition between Moose and Snowshoe Hares is limited because of differences in spatial use and browse heights (Dodds 1960; Oldemeyer 1983); however, the severity of the competition likely depends on the degree of browsing. Although the concurrent timing of the Moose irruption and the lynx extirpation raises the possibility of a cause-and-effect relation, confounding processes may have lessened the impact of Moose over-browsing on the lynx population. A die-off of thousands of Moose (Krefting 1974) would have provided a substantial supply of carrion for lynx that could have mitigated the short-term decline in hare abundance as lynx consume carrion when available and during periods of hare scarcity (Saunders 1963; Brand *et al.* 1976). Furthermore, the Isle Royale ecosystem includes alternative prey, specifically Red Squirrels (Adams 1909; Johnson 1969), which should have provided an important and relatively stable secondary prey (O'Donoghue *et al.* 1998) until hare numbers recovered. We suggest that systemic changes in habitat at Isle Royale — primarily related to Moose overabundance — might have contributed to the extirpation of Canada Lynx on the island.

Interactions with other predators: Coyotes appear to have colonized Isle Royale by 1912 (Krefting 1969). In the winter of 1916–17, trappers harvested 60 Coyotes from Isle Royale, but did not extirpate the population (Foster 1917). Cochrane (1996) reported an anonymous 1928 statement that "coyotes are becoming so numerous they threaten other wildlife." Lynx apparently disappeared from the island in the 1930s (Mech 1966; Johnsson *et al.* 1982; Martin 1988), a time when Coyotes were well established. Therefore, it is conceivable that Coyotes were a factor in the extirpation of lynx. Coyotes are suspected of being exploitative or interference competitors of Canada Lynx where their ranges overlap and may be contributing to range contraction and population declines of mainland lynx populations (Buskirk 2000). However, Murray *et al.* (2008) suggested that the evidence of inter-specific competition between Canada Lynx and Coyotes is weak. According to Cochrane (1996) and Cochrane (2013), Red Foxes (*Vulpes vulpes*) colonized the island in the 20th century; foxes could have competed with Canada Lynx for Snowshoe Hare and other small prey. However, Johnsson *et al.* (1982) reported that Red Foxes were scarce until Coyotes were extirpated, which apparently occurred in the 1950s (Mech 1966). The changing mammalian community, especially the presence of Coyotes, may have been a stress on the Canada Lynx population at Isle Royale.

Cyclical collapse in prey populations: The interacting temporal population dynamics of Canada Lynx and Snowshoe Hare are well known (Elton and Nicholson 1942; O'Donoghue *et al.* 2010), and hare population crashes are typically followed by lynx population crashes (Elton and Nicholson 1942; O'Donoghue *et al.* 2010). Historical and current evidence suggests that Isle Royale's hare population does oscillate (Martin 1988; Allen 1994; Vucetich and Peterson 2011). When Snowshoe Hare populations in Ontario crash, lynx are thought to emigrate in large numbers to Minnesota (Mech 1973; Gunderson 1978; Henderson 1978). Therefore, lynx could have emigrated from Isle Royale in response to a hare population decline.

However, Isle Royale is immediately east of the Ontario–Minnesota border so it is unclear whether Isle Royale would be a source or recipient of lynx during lows in the Ontario cycle. Furthermore, even if some lynx emigrated from Isle Royale during nadirs in the hare cycle, it is unlikely that all lynx would have left. In northern regions, lynx populations persist even through severe declines in hare populations (Poole 1994; O'Donoghue *et al.* 1997). Also, Red Squirrels should have provided an important alternative prey for lynx (O'Donoghue *et al.* 1998). Lynx remains were found on Isle Royale from pre-Columbian times, the species was abundant when the first people of European descent visited the island around 1850, and lynx were common up to the 1930s, suggesting that the population persisted on Isle Royale through numerous hare cycles (Figure 2).

Quantitative analysis of harvest impacts

Assuming a carrying capacity of 75 Canada Lynx, the reported historical harvests of 48, 67, and 25 animals resulted in a modeled 50-year population persistence of 15% (Table 2). When the harvest was increased

TABLE 2. Population viability (50-year) of Canada Lynx (*Lynx canadensis*) on Isle Royale under reported and assumed historical harvest rates, assuming a peak carrying capacity of 75 lynx.

Harvest option	Probability of persistence	Mean no. years of extinct runs	Mean final population size (extant runs only)
Assuming a 10-year population cycle			
48 lynx in year 13, 67 in year 26, and 5/year in years 40–44	0.154	19.9	35.0
53 lynx in year 13, 72 in year 26, and 10/year in years 40–44, plus 5 in each interim year	0.000	17.2	na
Assuming a 13-year population cycle			
48 lynx in year 13, 67 in year 26, and 5/year in years 40–44	0.278	37.8	31.5
53 lynx in year 13, 72 in year 26, and 10/year in years 40–44, plus 4 in each interim year	0.000	19.5	na

Note: na = not applicable.

by five lynx each year, to account for unreported harvest, the probability of persistence was 0% and the median time to extinction was 15 years. Correlating the reported harvest years with a modeled 13-year lynx cycle increased the probability of persistence to 28%, but, when we assumed an additional five lynx were harvested each year, the probability of persistence was 0%. The only harvest scenarios that produced a greater than 50% chance of lynx persistence for 50 years were those that assumed a carrying capacity of 113 lynx and/or no lynx harvest in interim years (Figure 3).

In non-harvest, 1000-year simulations, all of the cyclical and non-cyclical runs resulted in extinction within 400 years. Therefore, we ran simulations for 250 years and they resulted in a 14% chance of persistence for a cyclical population and a 42% chance of persistence for a non-cyclical population (Table 3). When inbreeding was disabled the probability of 250-year persistence increased to 100% for the cyclical scenario (Table 3). Supplementing the island population with 10 immigrants every 10th year increased the probability of persistence to 100% for both the 250-

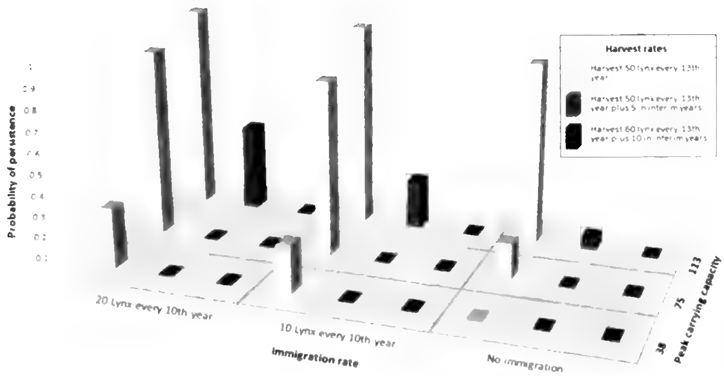

FIGURE 3. Probability of 50-year persistence of a population of Canada Lynx (*Lynx canadensis*) under a range of immigration rates, peak carrying capacities, and harvest rates.

TABLE 3. Population viability (250-year) of Canada Lynx (*Lynx canadensis*) on Isle Royale based on various non-harvest scenarios.

Scenario	Probability of persistence	Mean no. years of extinct runs (SD)	Mean final population size, extant runs (SD)	Final no. alleles*	Final expected heterozygosity
10-year cyclical population with peak carrying capacity of 75 lynx and inbreeding (baseline)	0.136	197.0 (36.1)	12.8 (13.4)	1.70	0.239
Assuming a non-cyclical population	0.417	207.6 (32.7)	19.7 (15.1)	2.01	0.321
Peak carrying capacity of 38 lynx	0.000	72.6 (26.8)	na	na	na
Peak carrying capacity of 113 lynx	0.941	226.0 (24.9)	64.4 (27.8)	3.26	0.510
Assuming no inbreeding depression	1.000	na	68.6 (8.8)	2.39	0.377
Assuming 10 immigrants every 10th year	1.000	na	70.1 (8.7)	37.41	0.926

*Using the VORTEX default infinite allele model.
Note: na = not applicable; SD = standard deviation.

year (Table 3) and 1000-year simulations even when inbreeding was enabled.

Quantitative analysis of changes in connectivity

The number of days each winter with ≥ 90% ice concentration between the mainland and Isle Royale declined significantly ($P < 0.01$) at a rate of 4.5% annually from a modeled 56 days in 1973 to 10 days in 2011 (Figure 4). Based on the Isle Royale Wolf–Moose Project binomial observations, the probability of an ice bridge forming in 1958–59 was 0.78 whereas in 2012–13 it was 0.10, a significant decline ($P < 0.01$: Figure 5). The Duluth Harbor station showed a significant ($P < 0.01$) annual decline of 0.6% in ice thickness over 1900–70 (Figure 6) whereas the Two Harbors and Keweenaw datasets each showed a 0.2% annual decline over the same period ($P > 0.05$).

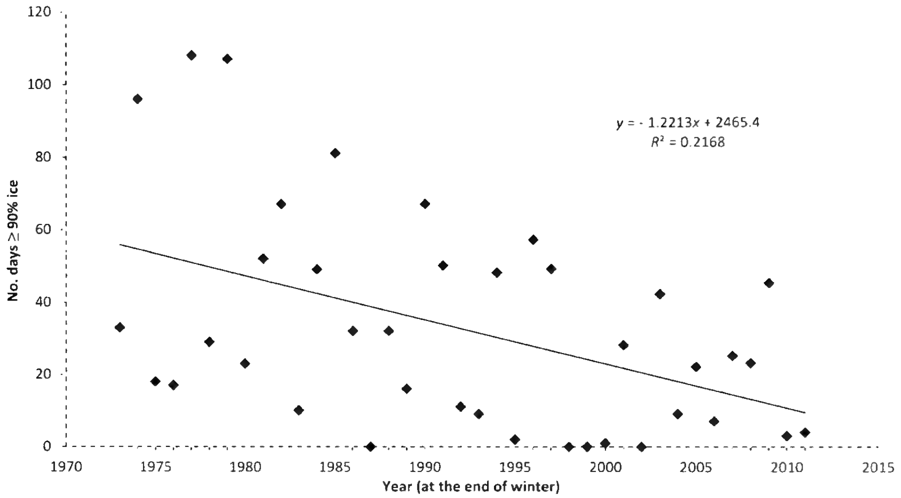

FIGURE 4. Number of days with ice concentration ≥ 90% between Isle Royale and the Minnesota–Ontario shoreline and linear regression trend. Source: Assel (2014*).

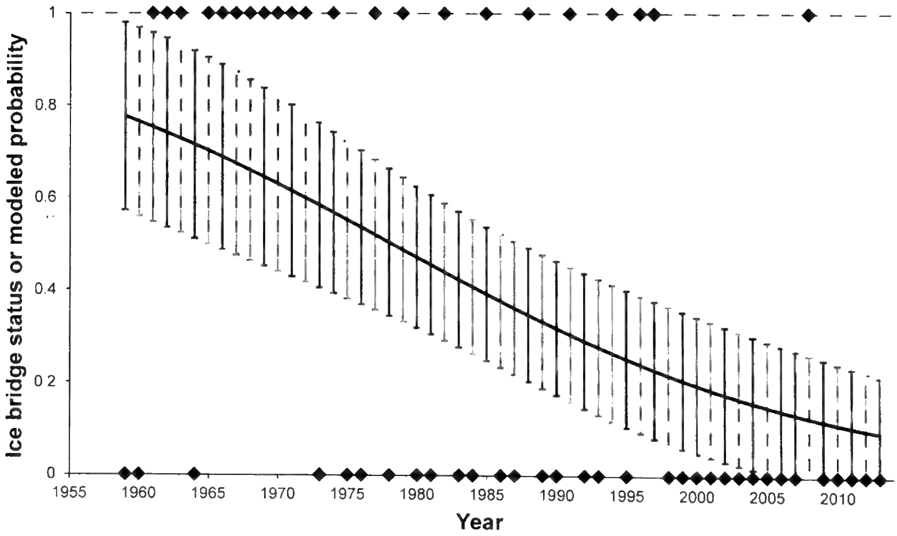

FIGURE 5. Observed (1 = yes, 0 = no) and logistic regression probability of ice-bridge formation based on visual observations. Error bars are approximate 95% point-wise prediction intervals. Source: Wolf–Moose Project (2013*) and R. Peterson (personal communication, 2014).

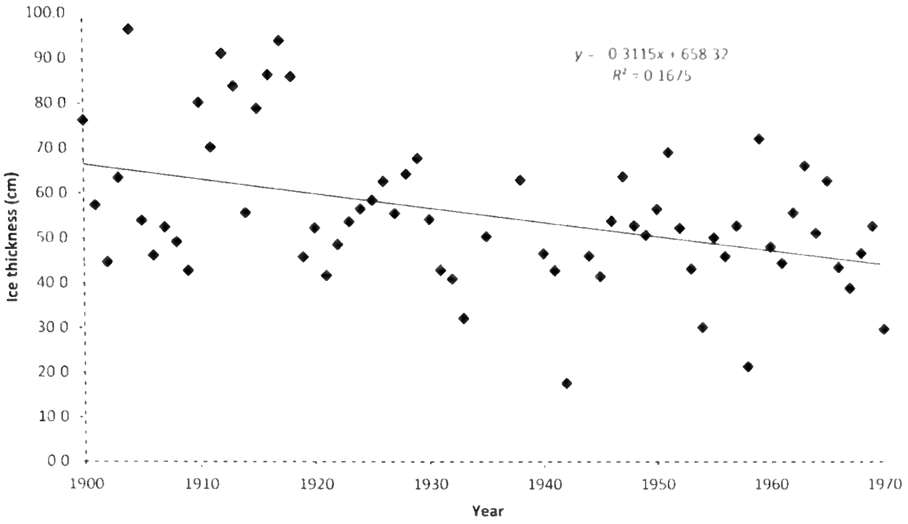

FIGURE 6. February–April ice thickness at Duluth Harbor, Minnesota, 1900–1970. Source: Assel (2004).

Discussion

The reasons for the extirpation of Canada Lynx from Isle Royale may never be fully understood, but, if the historical harvest records are accurate, then over-harvest alone could have caused the extirpation. Lynx populations are susceptible to over-harvest (Bailey *et al.* 1986; Slough and Mowat 1996), and such mortality is added to natural mortality (Brand and Keith 1979; Anderson and Lovallo 2003). Bailey *et al.* (1986) found that 80% of the marked lynx at their study site in Alaska were trapped within a year and Parker *et al.* (1983) estimated that 65% of their study population in Nova Scotia was removed by trapping. The idea that over-harvest caused the extirpation of lynx from Isle Royale has been suggested by others although no quantitative analysis appears to have been conducted. Mech (1966: 16) stated that people are "probably responsible for exterminating the Lynx." Martin (1988: 2) stated that "lynxes, like marten, were heavily trapped throughout the region during the early 1900s. Once the dominant predator on Isle Royale, they were extirpated in the 1930s after no less than four decades of systematic trapping."

Our analyses of the long-term viability of Canada Lynx on Isle Royale — even in the absence of harvest — indicate that the population needed immigrants to lessen the impact of inbreeding depression. Regular historical lynx immigration to Isle Royale is plausible. Both Schwartz *et al.* (2002) and Row *et al.* (2012) found high gene flow between lynx populations, even those separated by great distances. Dispersal of lynx appears to be substantial during the post-peak decline in the 8–11 year population cycle, with many animals traveling more than 100 km (Slough and Mowat 1996; Poole 1997). During lows in the Snowshoe Hare population cycle, large numbers of lynx may move southward into northern Minnesota in what has been termed an "invasion" (Mech 1973; Gunderson 1978; Henderson 1978). Dispersing lynx have been documented venturing hundreds of kilometres into treeless habitats and crossing frozen lakes (Mech 1973; Gunderson 1978; Ward and Krebs 1985; Devineau *et al.* 2010). Cochrane (2013) reported that ice-bridge formation was so substantial between Isle Royale and the mainland in the 1870s that draft horses and dog teams regularly crossed the ice. Thus, it is conceivable, even likely, that lynx historically crossed a 22-km ice bridge between the mainland and Isle Royale and, as a result, the population persisted for a long time. So why did immigration cease and why have lynx not recolonized the island?

The extirpation of lynx at Isle Royale occurred at a time when lynx populations were declining throughout the Great Lakes region due, in part, to unregulated harvest (Johnson 1922; de Vos and Matel 1952). The population decline and range contraction of mainland lynx may have reduced or eliminated immigration to Isle Royale during the period from 1930 to the 1960s. At the same time, changes in ice-bridge formation were occurring.

Our three ice-bridge analyses showed that the frequency of formation of an ice bridge between Isle Royale and the mainland is declining. Our results are corroborated by other studies of Great Lakes ice cover (Magnuson *et al.* 2000; Assel 2003; Wang *et al.* 2012). Assel (1990) showed that the decline in ice formation may have started in the late 19th century. More recently, the NOAA (2009) reported that densely packed ice near Great Lakes shores had declined about 20% from 1973–2002 and that Lake Superior has shown the greatest decrease in total ice cover of all the Great Lakes over the past several decades. Vucetich and Peterson (2011) reported that ice bridges between Isle Royale and the mainland have formed in only 2 of the past 15 years and one of those years was the only known instance of a wolf immigrating to the island since the 1940s. Vucetich *et al.* (2012) suggested that the decreasing frequency of an ice bridge, along with anthropogenic development along the Lake Superior shoreline (e.g., the Trans-Canada Highway and expansion of the city of Thunder Bay, Ontario) has significantly reduced the likelihood of wolf immigration to the island. Conversely, Mech (2013) suggested that climate change may not lead to a reduction in ice-bridge formation and, hence, there was no need to transplant wolves to the island for genetic augmentation; however, our analyses and corroborating evidence by others (Magnuson *et al.* 2000; Assel 2003; Wang *et al.* 2012) strongly indicate that the frequency of ice-bridge formation between Isle Royale and the mainland is declining due to climate change.

Climate change is widely identified as one of the major threats facing wildlife populations (Thomas *et al.* 2004). In Canada, climate change may disproportionately affect large-bodied mammals more than smaller ones (Imre and Derbowka 2011). The impacts on wildlife are generally thought to be via changes in plant communities, altered phenology, physiological stresses, changes in disease patterns, and escalating catastrophic weather events, among other factors (Gitay *et al.* 2002; Geyer *et al.* 2011; Nichols *et al.* 2011). The Interagency Lynx Biology Team (2013) categorized climate change impacts on lynx as shifts in distribution, changes in periodicity of the Snowshoe Hare cycle, reduction in lynx habitat and population size, changes in demographic rates, and changes in predator–prey relationships. Carroll (2007) and Gonzalez *et al.* (2007) speculated that climate change will decrease snow cover and reduce and degrade boreal habitat, resulting in local extirpations and range decline. We show that climate change can also reduce or eliminate metapopulation processes and contribute to local extirpations.

Conclusion

Our analyses suggest that Canada Lynx were extirpated from Isle Royale due to human activities and that over-harvest alone could have caused the extirpation. However, our analyses also suggest that climate change and the declining frequency of ice-bridge formation may prevent natural recolonization and reduce the viability of a future population, whether naturally recolonized or reintroduced by management. The Isle Royale situation exemplifies the notion that, as climate change reduces or eliminates connectivity, long-term conservation success may require periodic population augmentation to mitigate the loss of connectivity between populations.

Acknowledgements

We thank Rolf Peterson (Michigan Tech University) for allowing us to use the ice-bridge observations from the Isle Royale Wolf–Moose Study annual reports, his notes, and a helpful review of the document. Timothy Cochrane (Grand Portage National Monument, United States National Park Service) provided important historical information.

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Received 7 March 2014
Accepted 4 February 2015

Seventeenth Census of Seabird Populations in the Sanctuaries of the North Shore of the Gulf of St. Lawrence, 2010

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Rail, Jean-François, and Richard Cotter. 2015. Seventeenth census of seabird populations in the sanctuaries of the North Shore of the Gulf of St. Lawrence, 2010. Canadian Field-Naturalist 129(2): 152–158.

Seabirds in the 10 migratory bird sanctuaries of the North Shore of the Gulf of St. Lawrence, Quebec, Canada, which were created in 1925, have been censused regularly for the last 85 years. The sanctuaries support 16 seabird species, many of which are found in significant numbers. From 2005 to 2010, some notable population changes were observed: large increases in Common Murres (*Uria aalge*), Razorbills (*Alca torda*), and two species of cormorants and continuing declines in Black-legged Kittiwakes (*Rissa tridactyla*) and Atlantic Puffins (*Fratercula arctica*). The status of Leach's Storm-Petrel (*Oceanodroma leucorhoa*) and Caspian Tern (*Hydroprogne caspia*) is extremely precarious because of their small breeding populations. Between 2005 and 2010, seabird numbers in the sanctuaries increased 19% overall and were stable in most sanctuaries (≤ 15% change); however, notable increases were observed at Îles Sainte-Marie (60%), Baie des Loups (47%), and Île à la Brume (44%). Nonetheless, considering historical records, increased surveillance and raising of awareness of seabird conservation in local communities near the sanctuaries of Île à la Brume, Baie des Loups, and Saint-Augustin would be most beneficial.

Key Words: Seabirds; populations; North Shore; bird sanctuaries; Gulf of St. Lawrence; larids; alcids

Introduction

The migratory bird sanctuaries on the North Shore of the Gulf of St. Lawrence were created in 1925, following large and widespread seabird population declines. The declines were mainly the result of egging and hunting, practised initially primarily for subsistence and sport (Comeau 1909), but carried out more intensely for commercial purposes from the middle of the 18th century to the beginning of the 20th (Frazar 1887; De Puyjalon 1893; Blanchard 1984). The protection afforded by the sanctuaries preserved the remaining seabird populations and allowed some species to recover somewhat.

Currently, 10 migratory bird sanctuaries on the North Shore (Figure 1) are spread over 700 km of a coastline that comprises thousands of remote islands that can host seabird colonies. Thus, the sanctuaries protect only a small fraction of these islands. Nonetheless, seabirds are concentrated in these protected areas, which seem to act as reservoirs from which new colonies can establish elsewhere on the North Shore. In fact, the sanctuaries are home to 16 breeding seabird species (Table 1), and in many cases breeding numbers are significant at the regional or provincial scale, if not at the national or even continental scale. For example, according to Chapdelaine *et al.* (2001), they support two thirds of the Razorbills (*Alca torda*) breeding in the Gulf of St. Lawrence and 28% of the North American population; close to 95% of the Atlantic Puffins (*Fratercula arctica*) breeding in Quebec are found in these sanctuaries.

Seabird breeding populations have been censused nearly every five years in North Shore sanctuaries since they were created, i.e., for the last 85 years. The results of the previous 16 quinquennial surveys have been published by Lewis (1925, 1931, 1937, 1942), Hewitt (1950), Tener (1951), Lemieux (1956), Moisan (1962), Moisan and Fyfe (1967), Nettleship and Lock (1973), Chapdelaine (1980, 1995), Chapdelaine and Brousseau (1984, 1991), Rail and Chapdelaine (2004), and Rail and Cotter (2007). This is the only monitoring program in Quebec old enough to allow insight into seabird population trends from before the 1970s. The resulting database is certainly one of the very few in North America with such a long time series and such a wealth of historic data, and it is a valuable tool for the management and conservation of seabird populations in Quebec.

In this article, we aim to update population estimates and trends of seabird populations found in the sanctuaries of the North Shore of the Gulf of St. Lawrence. We also examine the status of each species and identify specific conservation issues that should be a priority.

Methods

Survey methods have been fairly constant from one census to the next and have been described in detail by Rail and Chapdelaine (2002) for the 1998–1999 census and more concisely by Rail and Cotter (2007) for the 2005 census. In the 2010 census, the method for loons, storm-petrels, cormorants, gulls, and terns remained unchanged; however, for Common Eiders (*Somateria mollissima*) and alcids, changes are described below. Unless otherwise indicated, if the method used resulted in an estimate of the number of breeding pairs or nests, these estimates were multiplied by two to obtain the total number of breeding birds (Table 1).

For Common Eider in the Île à la Brume sanctuary, a complete nest survey was conducted on six of the seven islands visited in previous censuses. These six

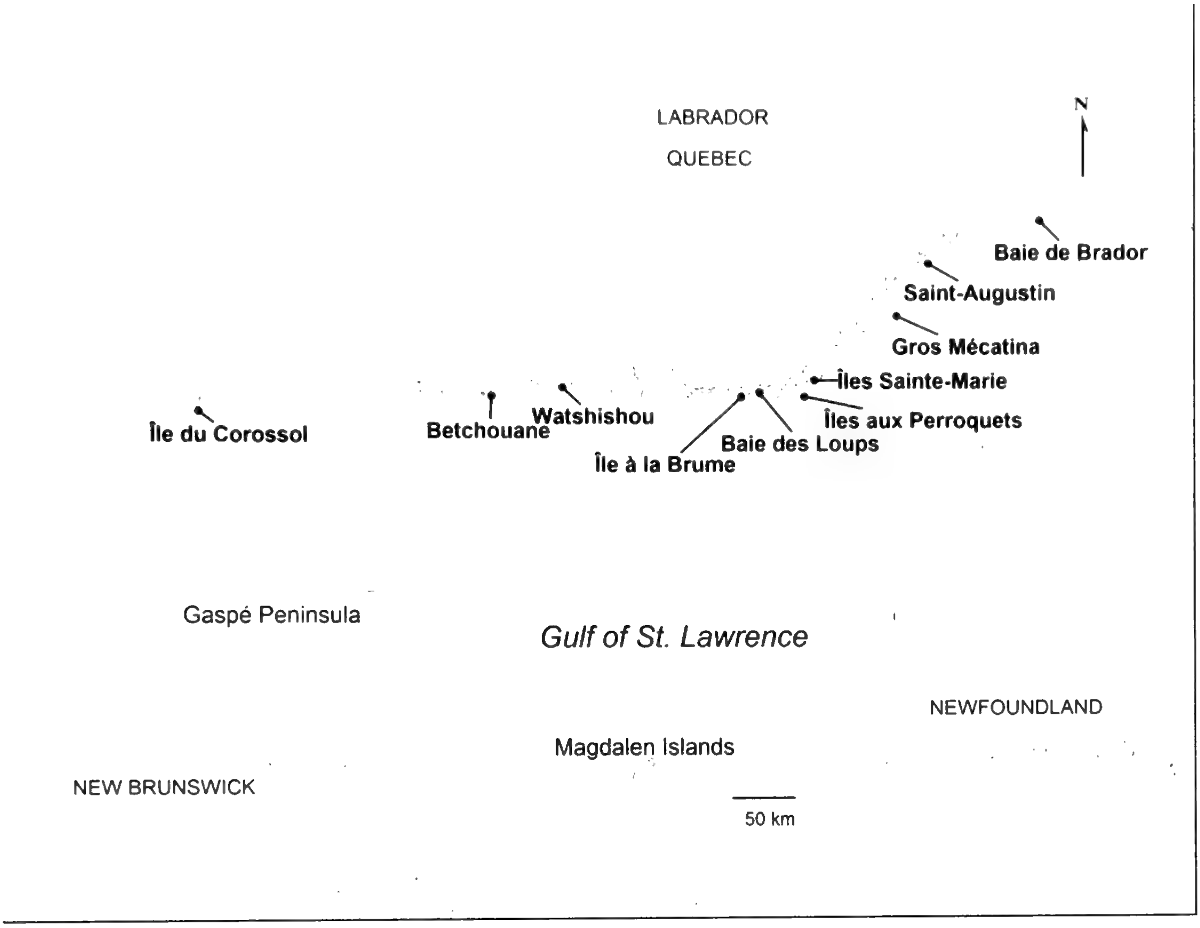

FIGURE 1. Location of the migratory bird sanctuaries on the North Shore of the Gulf of St. Lawrence, Quebec, Canada.

islands cover 21% of the sanctuary and the observed nest density was multiplied by the total land area of the sanctuary to estimate the total number of nests in the sanctuary. At Baie des Loups sanctuary, a complete nest survey was conducted on every island with the following exceptions: for Les Blacklands, nest density was calculated and extrapolated separately from 9% of open habitat and 9% of closed habitat (i.e., spruce thickets); for the Îles Factory archipelago, nest density was calculated for two islands, representing 25% of the total land area of the archipelago, and then extrapolated; and, finally, the nest density for Île no. 4 was applied to the adjacent Île no. 5. Approximately 40% of the Baie des Loups sanctuary total land area was censused.

For the four species of alcids at all colonies, adult bird counts were used to estimate the number of breeding individuals, except for the following colonies that were either small or easily accessible and, therefore, could be censused with minimal disturbance. In the Betchouane sanctuary, eggs of Common Murres (*Uria aalge*) and Razorbills and active burrows of Atlantic Puffins were counted to estimate the number of breeding pairs. Egg counts were also used at a few Razorbills colonies in the Île à la Brume, Baie des Loups, Îles aux Perroquets, and Îles Sainte-Marie sanctuaries, but these accounted for less than 2% of the total estimates of these four sanctuaries. In the Baie des Loups sanctuary, the number of Atlantic Puffins observed was multiplied by two to estimate the number of breeding pairs. This was done to allow better comparison with the 2005 results, when we had put considerable effort into calculating a correction factor at several subcolonies and had used a factor of 1.99 (number of active burrows per individual observed) to estimate the size of the puffin population there.

Results and Discussion

With confirmation of Leach's Storm-Petrels (*Oceanodroma leucorhoa*) nesting on Île du Corossol, a total of 16 seabird species were recorded breeding in North Shore migratory bird sanctuaries in 2010. The total seabird population increased nearly 20%, from 109 885 in 2005 to 130 407 in 2010, but individual species trends were extremely variable (Table 1 and Figure 2). Taking into account population trends and changes in distribution in North Shore sanctuaries since 1925, we present the situation for each species, in order of concern (least to most), followed by a summary and discussion of notable results for each sanctuary.

TABLE 1. Census of seabirds (number of individuals) in the migratory bird sanctuaries of the North Shore of the Gulf of St. Lawrence, Quebec, Canada, in 2005 and 2010.

	Île du Corossol		Betchouane		Watshishou		Île à la Brume		Baie des Loups		Îles aux Perroquets		Îles Sainte-Marie		Gros Mécatina		Saint-Augustin		Baie de Brador		All sanctuaries*		
Species	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	1998–99	2005†	2010
Common Eider *Somateria mollissima*	1960	1504	5596	6006	11024‡	12958‡	1004	1610	3898	3436	866	986	1218	1152	4	4	146	94	–	–	13072	25716	27750
Red-throated Loon *Gavia stellata*	–	–	–			–	2	4	6	12	28	30	54	52	2	4	–	–	–	–	82	92	102
Leach's Storm-Petrel *Oceanodroma leucorhoa*	–	72	–		–		–	–		–		–		–		–	–	–	–	–	718	0	72
Double-crested Cormorant *Phalacrocorax auritus*	312	316	–	–	1688	1888	–	–	–	40	–	–	1300	3245	46	–	–		–	–	2830	3346	5489
Great Cormorant *Phalacrocorax carbo*	–		–	–	–	–	–		–	–	2	–	46	156	–	78	–	–	–	–	342	48	234
Ring-billed Gull *Larus delawarensis*	–		–	–	54	414	48	174	–	128	1242	–	–	2	–	–	549	216	–	–	484	1893	934
Herring Gull *Larus argentatus*	1278	1040	1004	828	833	598	454	422	527	379	169	204	206	154	166	93	1102	1793	175	558	4988	5914	6069
Great Black-backed Gull *Larus marinus*	658	420	156	74	176	168	52	82	239	96	106	71	169	182	35	81	86	123	279	348	2427	1956	1645
Black-legged Kittiwake *Rissa tridactyla*	3318	1342	146	58	–		–		–		14	–	516	820	–	–	–	–	–	–	3856	3994	2220
Caspian Tern *Hydroprogne caspia*			–	–	–	–	3	3		–		–	–		–	–	–	–	–	–	0	3	3
Common and Arctic Terns *Sterna hirundo* and *S. paradisaea*	–	–			331	220	55	35	15	12	81	91	49	12	1789	8	987	645	4	–	394	3311	1023
Common Murre *Uria aalge*	522	1662	128	116	–	–	–	–	187	256	1598	2811	12131	20078	67	12	–	–	244	1402	30124	14877	26337
Razorbill *Alca torda*	2197	2799	328	346	–	–	–	10	1062	2984	5555	6864	8964	16547	192	280	–	–	4174	6283	14341	22472	36113
Black Guillemot *Cepphus grylle*	321	401	–	–	21	1	25	20	16	15	76	90	223	103	240	192	4	6	2	3	788	928	831
Atlantic Puffin§ *Fratercula arctica*	6	3	524	540		–			1774	4028	620	400	2208	837	123	59	–	–	20080	15718	29133	25335	21585
Total for sanctuary	10527	9559	7882	7968	14127	16247	1643	2360	7724	11386	10357	11547	27084	43340	2664	811	2874	2877	24958	24312	103579	109885	130407

*Totals for 1998–1999 are included for comparison; see also Figure 2 for compound growth rate by period (1999–2005 and 2005–2010).

†Totals for 2005 may differ slightly from those previously published (in Rail and Cotter 2007), as they include data from the Saint-Augustin sanctuary for better comparison with the 2010 totals.

‡The method used to estimate the Common Eider population in Watshishou likely resulted in a significant overestimate (possibly as much as two to fourfold; but see Rail and Chapdelaine 2002). We used this method for population trends analysis, e.g., to allow better historical comparisons (results were obtained with the same method in previous censuses).

§In 2005, the use of a burrow probe at a few sites at Baie des Loups, Îles aux Perroquets, and Baie de Brador verified that apparently occupied burrows were actually used at a fairly constant rate (71–76%). Therefore, the Atlantic Puffin population estimates for these sanctuaries, and for the Betchouane and Îles Sainte-Marie sanctuaries as well, are in reality overestimates because apparently occupied burrow counts were used. We did not apply a correction factor to these estimates as we wanted to be able to compare them with data from previous censuses.

Species' status

Razorbill

Increased by 61% between 2005 and 2010, and 2010 was the sixth consecutive census reporting an increase in this species. Razorbills are thriving, not only on the North Shore but also everywhere they breed in eastern North America (Chapdelaine *et al.* 2001; Cotter and Rail 2007; Rail 2009).

Common Eider

Increased marginally between 2005 and 2010, reaching a record level. The species is now more than three times as numerous as in any census between 1925 and 1988 and is currently second in abundance to the Razorbill.

Double-crested Cormorant

Increased by 64%, with numbers in 2010 the highest on record. Before 1988, the population never exceeded 700 pairs, but since then every census has recorded more than 1400 pairs. Since 1988, the drastic decline of the large colony at Île du Corossol has been offset by large increases in the Watshishou and Îles Sainte-Marie sanctuaries.

Common Murre

Increased 77% between 2005 and 2010. The population is now almost back to its 1998–1999 level, after an unexpected 51% decrease recorded in the 2005 census.

Red-throated Loon

Appears in good shape, even though the record number of 51 pairs in 2010 may not seem high. Although this species no longer breeds at Saint-Augustin and, historically, numbers have been much higher at Île à la Brume, the numbers of loons breeding at Baie des Loups, Îles aux Perroquets and Îles Sainte-Marie sanctuaries in 2010 were all at or near the highest ever recorded.

Black Guillemot

Although trends vary among sanctuaries, the total numbers of this species have been relatively stable in the last three censuses and near the highest levels ever observed.

Great Cormorant

Numbers have rebounded from only 23 nests in 2005, the lowest estimate since 1935, to 117 nests in 2010. However, this is still a third of the numbers seen in 1950–1960, and the Île Cliff colony (Îles Sainte-Marie sanctuary) appears to be the only well-established colony of the species in North Shore sanctuaries.

Herring Gull

The 2010 population was considerably lower than levels observed from the 1960s through the 1980s, before the collapse of the Atlantic Cod (*Gadus morhua*) fishery and the ensuing fishery moratorium in 1994, which eliminated fish offal and discards discharged at

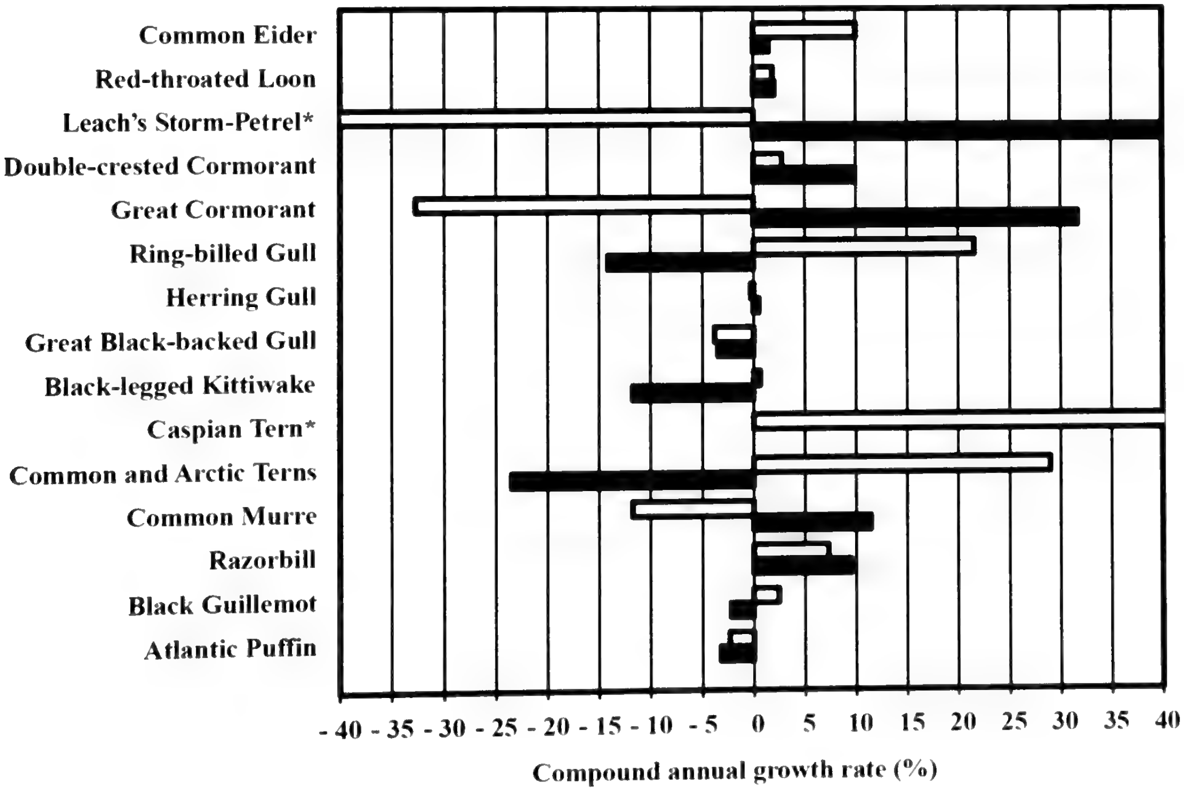

FIGURE 2. Compound annual growth rates of breeding seabird populations in the sanctuaries of the North Shore of the Gulf of St. Lawrence, Quebec, Canada, from 1999 to 2005 (white bars) and from 2005 to 2010 (black bars). Species marked with an asterisk have a compound growth rate greater than 40%, either positive or negative, because they either appeared or disappeared in the censuses.

sea by cod fishermen (see Chapdelaine and Rail 1997). Nevertheless, since 1993, the population has been fairly stable and numbers are now similar to or higher than they were before 1960.

Arctic Tern, Common Tern, and Ring-billed Gull

Tern populations decreased by 69% and numbers of Ring-Billed Gulls fell by half between 2005 and 2010. These declines resulted primarily from the disappearance of a large tern colony at Gros Mécatina and a large gull colony at Îles aux Perroquets. Population trends for these species are highly variable, as colonies tend to move in and out of sanctuaries and, consequently, our results may not be representative of trends for the whole North Shore. However, the 2010 population levels for these species were near the long-term average for 1925–2010.

Great Black-backed Gull

The census in 2010 was the second consecutive census to record a decline in numbers and there are now one-third fewer birds than there were in 1998–1999. However, this decline was mainly driven by a 64% decrease at Île du Corossol since 1998.

Atlantic Puffin

The last three censuses show a population decrease, to the second lowest population estimate since 1925. Nonetheless, in 2010, this was the fourth most abundant seabird in North Shore sanctuaries and was found breeding in seven. The colony at Baie des Loups had more than doubled in size in 2010, after a catastrophic decline (87%) noted at this sanctuary between 1993 and 2005.

Black-legged Kittiwake

Decreased by 44% between 2005 and 2010. Except for apparent stabilization between 1998–1999 and 2005, the number of Black-legged Kittiwakes has decreased in each census since 1988, and, as a result, there are now nearly 75% fewer birds. Most are found at Île du Corossol and kittiwakes are now also well established in the Îles Sainte-Marie sanctuary.

Leach's Storm-Petrel

The reappearance of 36 active burrows on Île du Corossol in 2010 was significant for the province, considering there are only two other known colonies (each with fewer than 20 pairs): Île Bonaventure on the Gaspé Peninsula and Île Brion in the Magdalen Islands (Rail 2009). However, a single small colony in all North Shore sanctuaries is a significant decline from 1988 when 872 nests were discovered on seven islands in four sanctuaries (Brousseau and Chapdelaine 1990).

Caspian Tern

In 2010, only three birds were observed, breeding was not confirmed, and there are no other known colonies in the Gulf of St. Lawrence. The 2010 census could have been conducted too early in the breeding season for this species, but a more likely explanation for so few observations is the finding on Île à la Brume of 87 empty and unattended Ring-billed Gull nests, among which Caspian Terns usually nest. Most clutches of Herring and Great Black-backed Gulls were still incomplete, which strongly suggests that eggs had been harvested.

Recent population trends by sanctuary

Some of the most recent local population trends in the migratory bird sanctuaries are noteworthy. Beginning from the west, between 2005 and 2010 the Île du Corossol sanctuary (surveyed 26–28 May) saw a three-fold increase in Common Murres, whereas its large kittiwake colony decreased by 60% (continuing a decline first noted in 1993). In the Betchouane sanctuary (visited on 30 May), the colony of Black-legged Kittiwakes, rather small compared with the one on Île du Corossol, also declined by 60%. Furthermore, the number of Great Black-backed Gulls was reduced roughly by half. In the Watshishou sanctuary (censused from 31 May to 4 June), the population of Ring-billed Gulls increased four-fold between 2005 and 2010. Razorbills were absent for the second census in a row, and the Black Guillemot may be the next species to disappear, as only a single individual was observed in 2010.

Razorbills, absent in 2005, reappeared at the Île à la Brume sanctuary (surveyed on 13 June). Until 2005, this alcid was present in every census since 1925. Common Eiders increased 60% and Ring-billed Gull numbers more than tripled between 2005 and 2010. In the past, alcids were much more abundant at this sanctuary and included several thousand Common Murres, which disappeared 50 years ago. This decline among alcids, as well as the fact that the Caspian Tern is on the verge of vanishing from its only know breeding site on the North Shore and the evidence of egg collection there, suggests that this sanctuary would benefit from better protection, despite the 44% increase in the total number of breeding seabirds between 2005 and 2010 (mostly attributable to the increase in eider numbers).

When we visited the Baie des Loups sanctuary (10 and 17 June), we found that the number of Razorbills had almost tripled since the last census, while the number of Atlantic Puffins had more than doubled (127% increase). Once a regular breeder, the Double-crested Cormorant was seen breeding at Baie des Loups for the first time in over 30 years. Combining all species, the number of seabirds grew by 47% from 2005 to 2010, and only the Great Black-backed Gull exhibited a large decline (60%). Despite encouraging trends for Razorbills and Common Murres, this sanctuary has a severely impoverished alcid community compared to historical levels (Rail and Chapdelaine 2002; Rail and Cotter 2007).

At Îles aux Perroquets (surveyed 15–16 June), Great Cormorant, Black-legged Kittiwake, and Ring-billed Gull were not seen; however, these species have never bred regularly or in large numbers in this sanctuary (first censused in 1982). Other notable trends at this sanctuary included an increase in the number of

Razorbills (24%) and Common Murres (77%), but a 35% decrease in Atlantic Puffins.

At Îles Sainte-Marie (on 8, 9, 11, 12, 16, and 18 June), we found large increases in the number of Great (239%) and Double-crested (150%) Cormorants since 2005. With 1290 nests, the colony at Île de l'Est is the largest cormorant colony ever recorded in North Shore sanctuaries. Razorbills (85%), Common Murres (66%), and Black-legged Kittiwakes (59%) also experienced large increases in the sanctuary, whereas Black Guillemots and Atlantic Puffins suffered declines of 54% and 62%, respectively. Overall there was a 60% increase in the total seabird population between 2005 and 2010, and this sanctuary is now home to a third of all seabirds breeding in North Shore sanctuaries (and to 76% of all Common Murres and 46% of all Razorbills).

At Gros Mécatina sanctuary (19 June), only six tern nests were found on Île Plate, compared to 887 nests in 2005. However, excluding terns, the number of seabirds varied little over the three previous censuses. The 23 Double-crested Cormorant nests found in 2005 on Île aux Trois Collines were replaced by 39 Great Cormorant nests in 2010. Among North Shore sanctuaries, Gros Mécatina has the second smallest land area and, in 2010, only 0.6% of the total seabird population.

In contrast, Saint-Augustin is the largest sanctuary, but, on 21 June 2010, it had the third smallest seabird population, with only 2877 breeding individuals of six species. Nearly the entire seabird breeding community is represented by larids (terns and gulls, 97%). Herring and Great Black-backed Gulls increased from 2005 by 63% and 43%, respectively, but the smaller Ring-billed Gull experienced a 61% decline. Only 47 Common Eider nests were found, compared to 73 nests in 2005. The Common Eider population is only 7-10% of what is was between 1925 and 1960. The islands in this sanctuary are used extensively by nearby communities, and direct exploitation, by egg harvesting and hunting of young and adult seabirds of many species, is a tradition still practised in most local villages on the North Shore, by both Innu and non-native peoples (Blanchard 1984; Agence Mamu Innu Kaikusseht 2014*).

The Baie de Brador sanctuary (Île Verte surveyed on 23 June and Île aux Perroquets on 24 and 27 June) has the highest density of breeding seabirds of all North Shore sanctuaries. Nevertheless, its most abundant seabird, the Atlantic Puffin, decreased by 22% between 2005 and 2010. This decline was partly counterbalanced by the spectacular growth of the Common Murre (475% increase) and Razorbill (51% increase) populations. Common Murre was confirmed breeding here for the first time fairly recently (seven pairs in 1999), while Razorbills have been increasing in numbers since 1982. Herring and Great Black-backed Gulls are much less abundant, but they too have been growing at a fast rate since 1988, when only two individuals of each species were noted.

In conclusion, Île à la Brume, Baie des Loups, and Saint-Augustin sanctuaries are facing the greatest conservation challenges, as current seabird populations are far below historical levels; therefore, they would benefit most from conservation efforts. These are the same sanctuaries that were highlighted after the 2005 census, and the recommendations we made then (Rail and Cotter 2007) regarding the need for better law enforcement and educational programs still hold. Moreover, we suggest that a population study of Atlantic Puffins would be useful if we want to understand why they are decreasing. A restoration project on Île à la Brume could be very beneficial to the Caspian Tern while there are still a few individuals breeding there, albeit sporadically.

Acknowledgements

Carrying out this census would not have been possible without the contribution of many people. We thank Louis Gallienne and his family for their warm hospitality on Île du Corossol. Our colleagues, Pierre Brousseau, Myriam Drolet-Lambany, Patrick Labonté, Myriam Trottier-Paquet, as well as Environment Canada's wildlife enforcement officers, Wilson Evans, Wayne Foreman, and Pascal Gagnon, provided essential field assistance. In Havre Saint-Pierre, Parks Canada personnel and the group of volunteers they recruited worked very hard with us at the Betchouane and Watshishou sanctuaries. Our acknowledgements also go to Christine Vatcher (Îles Sainte-Marie migratory bird sanctuary) and Perry McKinnon who guided us through the archipelago of the Saint-Augustin sanctuary. Finally, at Baie de Brador, we had a considerable help from Trish Nash and interns Stefan Crampton and Curtis Walsh from the Quebec-Labrador Foundation and boatman Jean-Marie Jones who took us to the islands.

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Received 12 June 2014
Accepted 3 May 2015

Kleptoparasitism by Bald Eagles (*Haliaeetus leucocephalus*) as a Factor in Reducing Peregrine Falcon (*Falco peregrinus*) Predation on Dunlin (*Calidris alpina*) Wintering in British Columbia

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Dekker, Dick, and Mark C. Drever. 2015. Kleptoparasitism by Bald Eagles (*Haliaeetus leucocephalus*) as a factor in reducing Peregrine Falcon (*Falco peregrinus*) predation on Dunlin (*Calidris alpina*) wintering in British Columbia. Canadian Field-Naturalist 129(2): 159–164.

Kleptoparasitism, or food piracy, is common in a wide range of taxa, particularly among predators, with the larger species forcing smaller species to surrender their catch. The Bald Eagle (*Haliaeetus leucocephalus*) is known to rob Peregrine Falcons (*Falco peregrinus*) of just-caught prey. We present time series of kleptoparasitic interactions between eagles and peregrines hunting Dunlin (*Calidris alpina*) that were wintering at Boundary Bay in the Fraser River valley, British Columbia. In 1108 hours of observation during January, intermittently between 1994 and 2014, we recorded 667 sightings of Peregrine Falcons, including 817 attacks on Dunlin resulting in 120 captures. The population of wintering Bald Eagles in the study area increased from about 200 in 1994 to 1800 in 2014, while the rate of kleptoparasitism at the expense of peregrines increased from 0.05 to 0.20. The increase in the number of Bald Eagles coincided with a decline in January sightings of Peregrine Falcons, which suggests that some falcons may have left the study area because of interference from eagles. The decrease in Peregrine Falcon numbers can be expected to have led to reduced predation risk for Dunlins. Christmas Bird Counts conducted in the Fraser River Valley have underscored the fluctuation in eagle and peregrine numbers reported here.

Key Words: Bald Eagle; *Haliaeetus leucocephalus*; kleptoparasitism; Peregrine Falcon; *Falco peregrinus*; predation; Dunlin; *Calidris alpina*; British Columbia

Introduction

Kleptoparasitism by animals pertains to the opportunistic or habitual stealing of food from other animals. The kleptoparasite benefits by eating food that it could not have obtained itself or by saving energy by not having to search for or capture that food (Shealer *et al.* 2005). Kleptoparasitism is particularly common in waterbirds, including gulls, skuas, jaegers, and frigatebirds (Furness 1987; Calixto-Albarran and Osorno 2000), and it has been documented for numerous Falconiformes (Brockmann and Barnard 1979; Paulson 1985). Among raptors, intraguild kleptoparasitism benefits larger species over smaller species or smaller conspecifics. For instance, in Alberta and British Columbia, Peregrine Falcons (*Falco peregrinus*) were forced to surrender their prey to pursuing *Buteo* hawks, and Merlins (*Falco columbarius*) were kleptoparasitized by peregrines (Dekker 1980, 2009). Similarly, female peregrines commonly rob male peregrines, which are comparatively smaller than females (Cade 1982; White *et al.* 2002).

The inter- and intraspecific kleptoparasitic habits of the Bald Eagle (*Haliaeetus leucocephalus*) are well known (Palmer 1988; Buchler 2000). Jorde and Lingle (1998) reported that stealing fish and waterfowl from other raptors was a major food-gathering method of eagles wintering in Nebraska. On the Pacific coast of British Columbia, Bald Eagles commonly kleptoparasitized gulls and crows, as well as conspecifics, and they routinely robbed peregrines of captured seabirds (Dekker and Bogaert 1997; Dekker 1999). On Vancouver Island, eagles pirated 13 (28%) of 46 ducks captured by wintering peregrines, and, in central Alberta, Bald Eagles took four (25%) of 16 ducks from wintering Gyrfalcons (*Falco rusticolus*) (Dekker 1995; Dekker and Court 2003). On Vancouver Island and in the Fraser River Valley, peregrines lost just-caught ducks and Dunlin (*Calidris alpina*) to Gyrfalcons and Bald Eagles (Dekker *et al.* 2012).

After a numeric low in the mid-1900s, Bald Eagle populations have recovered in much of North America (Buchler 2000; Watts *et al.* 2007; Elliott *et al.* 2011; Hipfner *et al.* 2012; Elderkin 2014). Bald Eagles are year-round residents at Boundary Bay near Vancouver, British Columbia, and, in the lower Fraser River Valley, nesting territories increased from two in the 1960s to 108 in 2008 (Hancock 2003; Goulet 2009). At Boundary Bay, resident eagles are joined by migrants that begin arriving in October and reach peak numbers in January (Dekker *et al.* 2012). The wintering population has grown since 1994. In an eight-year census at the Vancouver Regional Landfill, eagles peaked at 453 in 2001 (Elliott *et al.* 2006). In an ongoing census at the same landfill, 1812 eagles were counted on 1 January 2014 (D. Hancock, personal communication).

The growing number of Bald Eagles on the coast of British Columbia and their increasing kleptoparasitic pressure on Peregrine Falcons was investigated by Dekker (1999, 2003), who reported that wintering falcons had stopped hunting ducks and, instead, concentrated on smaller prey such as Dunlin (*Calidris alpina*), which could be carried away out of reach of pursuing eagles. In 2006–2011, as eagle numbers continued to grow, the falcons increased their kill rate of Dunlin by 72% to compensate for prey losses. Given a further increase in kleptoparasitic pressure from eagles, Dekker *et al.* (2012) predicted a decline in peregrine numbers on the intertidal coast. This paper presents time series of peregrine counts and behavioural observations of hunts by peregrines on Dunlin wintering in Boundary Bay between 1994 and 2014. Empirical data (peregrine sightings per hour and hunting success) are combined with Christmas Bird Count (CBC) numbers to evaluate temporal trends in abundance of Dunlin and raptors and test the hypothesis that kleptoparasitism by Bald Eagles on Peregrine Falcons has reached a "tipping point," leading some peregrines to depart coastal hunting grounds in the Fraser River Delta.

Study Area

The study area is at Boundary Bay in the Fraser River estuary of southwestern British Columbia (49°05'N, 123°00'W). The bay is 16 km across, and the intertidal zone is roughly 5 km wide at the lowest ebb. The tide flats are bordered by a strip of salt marsh up to 150 m wide. A gravel road on a 2-m high dike separates the coastline from low-lying agricultural fields and meadows inland. Boundary Bay is a major stopover for migratory waterbirds. Dunlin begin arriving in October and stay until April. Estimated at about 40 000 birds, the Dunlin population can be substantially higher in late November or temporarily absent during periods of low temperatures when the bay freezes over (Ydenberg *et al.* 2010; Dekker 2013; Drever *et al.* 2014). The only other shorebird to winter in appreciable numbers (about 1000) is the Black-bellied Plover (*Pluvialis squatarola*). Mallards (*Anas platyrhynchos*), Northern Pintails (*A. acuta*), American Wigeon (*A. americana*), and Green-winged Teal (*A. crecca*) congregate in late summer and stay well into March. Bald Eagles and other diurnal raptors, including Peregrine Falcons, occur year-round. For a more detailed description of the delta and its avifauna, see Butler and Campbell (1987).

Methods

Behavioural observations

Although visits to the study area took place in all months of the year, only January visits were considered for the analysis of changes in peregrine sightings and kleptoparasitic events because the number of locally wintering eagles was at its peak in January (Dekker *et al.* 2012). During January of 11 winters between 1994 and 2014, DD spent 1108 hours in the study area. Observations were conducted from a vehicle parked on the dike at locations with an unobstructed view of the tide flats or during short walks on the dike to remain in view of the largest Dunlin concentrations. Methods for recording peregrine attacks on waterbirds and kleptoparasitic interactions by eagles have been described in previous studies (Dekker 2003, 2013).

Christmas Bird Counts

Observations were augmented with annual counts of wintering Bald Eagles, Peregrine Falcons, and Dunlin obtained from the CBC. The CBC is a survey administered by the National Audubon Society and conducted annually by volunteer birdwatchers on a single day from December 14 to January 5. Counts are restricted to a "count circle" with a diameter of 24 km in which more than 10 volunteers follow assigned routes counting every bird they see. Data were obtained from the count circle at Ladner, Delta, British Columbia (BCLA), 1994 to 2013 (Audubon 2013*). The BCLA includes Boundary Bay and the Vancouver Regional Landfill site. One year, 1996, was excluded from our analyses because of low participation in the CBC and continuing heavy snowfall on count day.

Statistical methods

Three measures of peregrine abundance and hunting success were derived from behavioural observations: (i) peregrine sightings, calculated as the total number of peregrines detected over the field season divided by the number of observation hours to derive an average number of sightings per hour of observation, (ii) kleptoparasitism rate, defined as the proportion of observations in each field season during which eagles chased peregrines carrying prey, and (iii) hunting success, measured as the proportion of hunts by Peregrine Falcons in each field season that resulted in successful capture of prey.

Temporal trends in peregrine sightings, kleptoparasitism, and hunt success were estimated using generalized linear models (GLMs) in R 3.2.0 (R Foundation for Statistical Computing, Vienna, Austria). Each response variable was modeled as a function of relation to year from 1994 to 2014, with the year value reset, such that 1994 had a value of 1. Peregrine sightings were modeled as a Poisson-distributed variable suitable for count data, and the model included log-transformed number of observation hours as an offset to account for variable effort over time. Kleptoparasitism and hunt success were modeled as probabilities using a binomial distribution. To allow for non-linear trends over time, trend models included both a linear and a quadratic term for year. If the quadratic term was not significant, it was removed and inference was drawn from the simpler linear model.

Temporal trends in CBCs were estimated using generalized additive models (GAMs) by modeling response variables in relation to year, from 1994 to 2014, using package mgcv in R. The GAM approach is an extension of the GLM in which predictors are smoothed functions rather than linear relationships (Wood 2006), and it allows the fitting of non-linear trends over time. For eagles, the total number of birds was used as it provided a better representation of eagle abundance, and eagle detection is not heavily influenced by the number of observers (Elliott *et al.* 2011). For peregrines and Dunlin, the number of birds was divided by the total party-hours to account for variable survey effort, and this variable was used as the response variable in trend models that fit a smooth curve as a function of year. For peregrines and eagles, the response variables were log-transformed to normalize residuals.

Results

At Boundary Bay, peregrine sightings during January increased over time and then decreased sharply in the last two years (2012, 2014) of observation (Table 1, Figure 1); the trend model included a significant quadratic term (Table 2). Beginning with 0.36/h in 1994, peregrine sightings increased over time, nearly tripling to reach peak values of 0.93/h and 1.04/h in 2006 and 2011, then declining to 0.37/h in 2014.

During 1108 hours of observation in January 1994–2014, eagles attempted to interfere with hunting peregrines 101 times. On 48 occasions, prey-carrying falcons managed to stay ahead of pursuing eagles, but in 17 cases eagles succeeded in securing a Dunlin dropped or struck down by peregrines. In 36 instances, one or more eagles (range 1–12 eagles) left their perches to approach falcons attacking Dunlin some distance away. If the falcon was unsuccessful in catching prey or aborted its hunt, the eagles turned back. In 10 of these instances, the peregrine swooped aggressively at the eagles. Over the years, the frequency of kleptoparasitic events increased and subsequently declined again, roughly in parallel with the fluctuation in peregrine sightings (Figure 1).

Peregrines were observed hunting Dunlin 817 times, resulting in 120 captures, representing an overall hunt success rate 14.7.0%. Hunt success varied over time, and the trend model showed a significant increase in mean hunt success from 1994 to 2014 (Table 2, Figure 1), although hunt success of 4.5% in 2014 was the lowest recorded

Christmas Bird Counts

The number of eagles counted in the Ladner CBC circle ranged from 200 to 210 between 1994 and 2004,

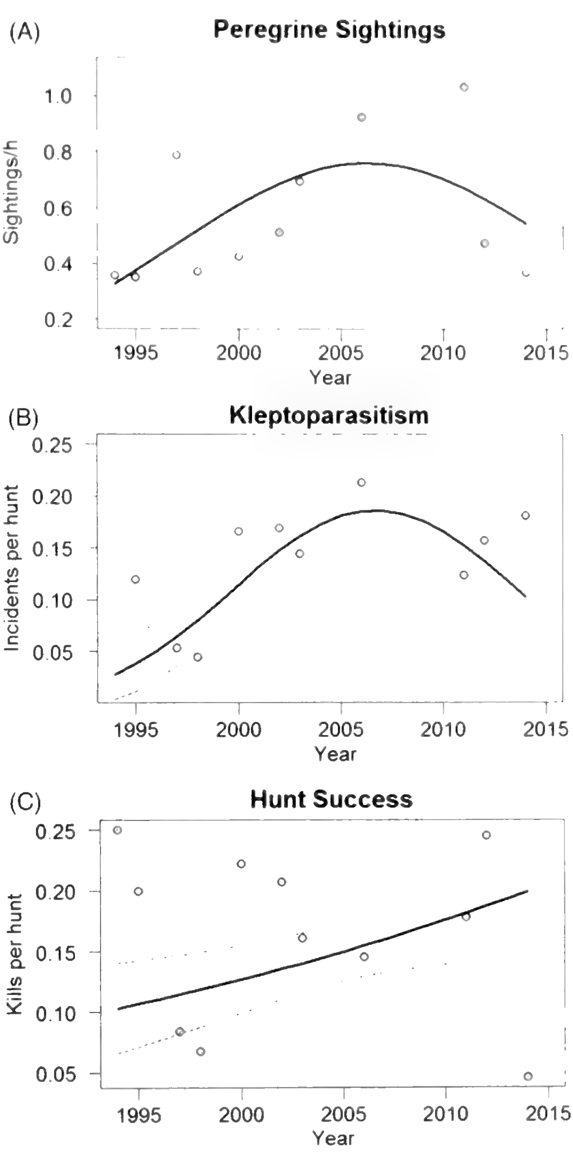

FIGURE 1. Temporal trends in Peregrine Falcon (*Falco peregrinus*) (A) sightings, (B) kleptoparasitism rate, and (C) hunt success observed during Januarys at Boundary Bay, Delta, British Columbia, 1994 to 2014. Solid line shows estimated trend; dashed lines indicate 95% confidence interval.

TABLE 1. Observations of Peregrine Falcons (*Falco peregrinus*) hunting Dunlins (*Calidris alpina*) during January of 11 years between 1994 and 2014 at Boundary Bay, British Columbia.

Month	Hours of observation	Sightings	Sightings/h	Hunts	Hunts/h	Kills	% success
Jan. 1994	14	5	0.36	4	0.29	1	25.0
Jan. 1995	91	32	0.35	25	0.27	5	20.0
Jan. 1997	118	93	0.79	167	1.42	14	8.4
Jan. 1998	126	47	0.37	89	0.71	6	6.7
Jan. 2000	89	38	0.43	36	0.40	8	22.2
Jan. 2002	144	74	0.51	53	0.37	11	20.8
Jan. 2003	89	62	0.70	62	0.70	10	16.1
Jan. 2006	123	114	0.93	117	0.95	17	14.5
Jan. 2011	110	114	1.04	185	1.68	33	17.8
Jan. 2012	120	57	0.48	57	0.48	14	24.6
Jan. 2014	84	31	0.37	22	0.26	1	4.5
Total	1108	667	0.60	817	0.74	120	14.7

TABLE 2. Estimates for trend models of behavioural observations of hunting Peregrine Falcons (*Falco peregrinus*) at Boundary Bay, Delta, British Columbia, 1994–2014, with 1994 set to a value of 1.

Parameter	Estimate	SE	*Z*-value	*P*
Peregrine sightings				
Intercept	−1.114	0.133	−8.40	< 0.001
Yr	0.137	0.029	4.74	< 0.001
Yr^2	−0.006	0.001	−4.29	< 0.001
Kleptoparasitism				
Intercept	−3.537	0.456	−7.75	< 0.001
Yr	0.326	0.098	3.32	< 0.001
Yr^2	−0.013	0.004	−2.88	< 0.001
Hunt success				
Intercept	−2.160	0.204	−10.57	< 0.001
Yr	0.039	0.016	2.35	0.02

Note: SE = standard error.

and then increased from 2005 to 2013 to more than 1000 (Figure 2). The GAM model indicated that this pattern was statistically significant (estimated df = 3.1, residual df = 3.9, $F = 16.3$, $P < 0.001$).

The Ladner CBC data indicate that peregrines were also relatively scarce at the beginning of the time series, with 0.02–0.05 birds per party-hour observed between 1994 and 2000. Peregrine counts then increased from 2001 onward, reaching the highest value of 0.11/party-hour in 2011 (Figure 2), but then declining to 0.05/party-hour in 2014. This pattern was statistically significant (GAM model: estimated df = 5.2, residual df = 6.2, $F = 11.3$, $P < 0.001$). The high recorded in 2011 coincided with the year in which we observed the greatest number of falcons per hour at Boundary Bay (Table 1).

Dunlin counts from the Ladner CBC also increased over time, ranging from 23 to 148/party-hour from 1994 to 1999, and then increasing and leveling off at 118–290/party-hour from 2010 to 2014. The GAM model indicated that this pattern was statistically significant (estimated df = 1.9, residual df = 2.4, $F = 3.7$, $P = 0.04$).

Discussion

Although Bald Eagle counts over the Strait of Georgia are reported to have shown no region-wide trend over the past decade from 1999 to 2011 (Crewe *et al.* 2012), the steep increase in the number of eagles in the Boundary Bay study area is remarkable. The causative explanation is related to three factors: (1) Boundary Bay offers a rich food base for eagles that hunt waterfowl and habitually kleptoparasitize gulls (Dekker 1999); (2) the regional landfill 3 km inland attracts masses of scavenging eagles (Elliott *et al.* 2006) that disperse to Boundary Bay at low tide; and (3) declining spawning runs of Chum Salmon (*Oncorhynchus keta*) in southwestern British Columbia force eagles to abandon inland rivers and switch to coastal foraging locations (Elliott *et al.* 2011).

Crewe *et al.* (2012) reported no region-wide trend in Peregrine Falcon sightings, whereas our behavioural observations at Boundary Bay and the Ladner CBC

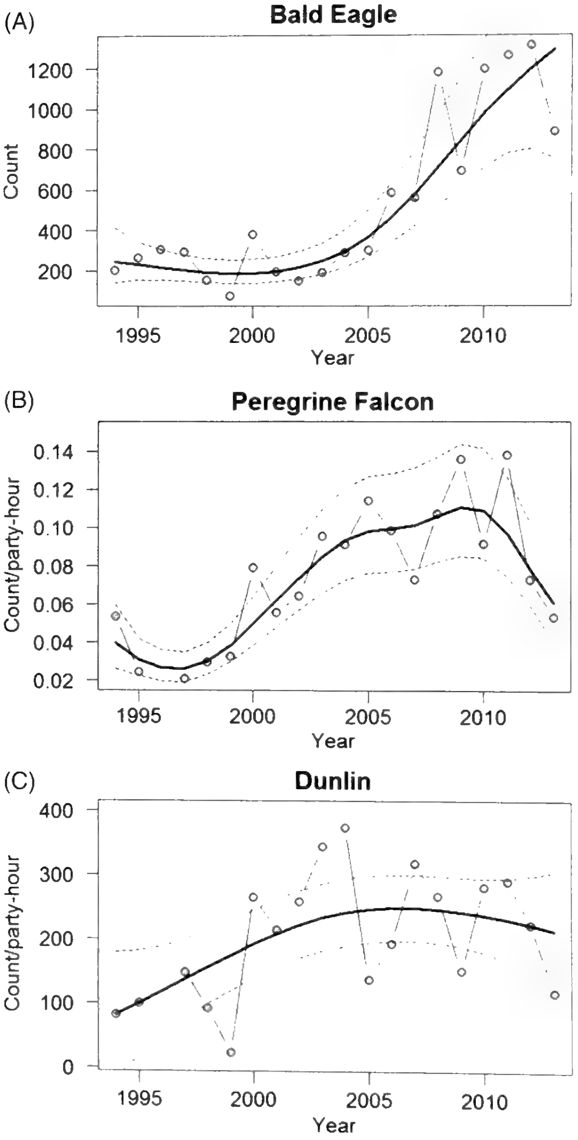

FIGURE 2. Temporal trends in numbers of (A) Bald Eagles (*Haliaeetus leucocephalus*), (B) Peregrine Falcons (*Falco peregrinus*), and (C) Dunlins (*Calidris alpina*) in the Ladner circle of the Audubon Christmas Bird Count, British Columbia, conducted in December from 1994 to 2013. Solid line shows estimated trend; dashed lines indicate 95% confidence interval.

data indicate that the local peregrine population increased over time, and subsequently declined at Boundary Bay in 2012–2014. Dunlin numbers increased during 1994–2014, as did hunt success of peregrines, indicating that prey sources remained available over this period (Drever *et al.* 2014). Bald Eagles also increased during this period and became persistent kleptoparasites of hunting peregrines, taking 10–20% of captured Dunlin. These results support the prediction made by Dekker *et al.* (2013) that continued interference by eagles would result in the abandonment of the shoreline study area by some peregrines.

Although this study focused on kleptoparasitism, eagles may affect hunting peregrines in other ways. Over the course of this study, a routine method for surveying falcons was to drive the dike road and check driftwood logs. In 2014, one or more eagles — as many as 17 in one case — took up all prominent driftwood logs at high tide, leaving no room for falcons. This apparent competition for shoreline perches may in itself have been a reason why some falcons left the coast.

The success rate of falcons hunting Dunlin shows a slight increase over time from 14.4% in 1994–2003 to 16.9 % in 2006–2014 (Table 1; Figure 1). We hypothesize that the increase in success rate is linked to the growing pressure from kleptoparasites, because, after eagles began to dominate the coast, the only falcons that managed to cope were the better hunters, which were able to catch a Dunlin quickly, allowing enough time to escape before the arrival of kleptoparasites. Therefore, the increasing proportion of experienced hunters would have resulted in higher hunt success over time.

Hunting success rates differ between immature and adult peregrines (Dekker 1980, 2009). At Boundary Bay, immature peregrines made a catch in 9% of 399 Dunlin hunts, significantly less than the 27% success of adult peregrines in 164 hunts (Dekker 2003). After their initial attack fails, first-year falcons commonly persist with long pursuits and multiple swoops at their intended prey (Dekker 1988, 1999). In contrast, adults sometimes take a Dunlin by surprise at the first pass. By virtue of their expertise as hunters, adult peregrines often have time to carry their prey away before potential kleptoparasites approach. Conversely, because of the extended time a young falcon may need to secure its prey, interference from eagles can become a serious hindrance. Harassed by kleptoparasites, immature falcons probably depart the coast for inland regions where eagle numbers may be lower.

The findings of this study support the hypothesis that the increase in the population of kleptoparasitic Bald Eagles has resulted in a local decline in Peregrine Falcon numbers at Boundary Bay between 2005 and 2014. The decline was most pronounced, in both our counts and the CBCs, during a limited number of years from 2012 to 2014, and it remains to be seen whether these low peregrine counts represent the "new normal" given the continuing high abundance of Bald Eagles. Peregrines are important predators of shorebirds (Ydenberg *et al.* 2010), and, therefore, a continuing lower abundance of peregrines should result in a reduction of predation risk to wintering Dunlin, indicative of the cascading effect that can occur when top predators return to an ecosystem.

Acknowledgements

We thank the Corporation of Delta, British Columbia, for access to the dike at Boundary Bay. Partial funding for D. D.'s field studies in 2002–2012 was provided by the Centre for Wildlife Ecology, Simon Fraser University. Fieldwork in 2012–2014 was funded by the Canadian Wildlife Service, Environment Canada.

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Received 17 September 2014
Accepted 21 February 2015

Apparent Extirpation of Prey Fish Communities Following the Introduction of Northern Pike (*Esox lucius*)

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Nicholson, Michele E., Michael D. Rennie, and Kenneth H. Mills. 2015. Apparent extirpation of prey fish communities following the introduction of Northern Pike (*Esox lucius*). Canadian Field-Naturalist 129(2): 165–173.

We examined the long-term effects on prey fish communities of introducing Northern Pike (*Esox lucius*), a top predator fish, into small, Boreal Shield lakes lacking natural piscivore populations. During 1987–1994, Northern Pike were introduced into Lakes 110, 221, and 227 in the Experimental Lakes Area in northwestern Ontario, Canada. In Lake 227, prey fish were undetectable three years after the addition of Northern Pike. Although Northern Pike were removed from the lake by 1996, multiple independent visual and trapping surveys have yielded no evidence of any fish in Lake 227 since then. In 1994–1995, 85% of the Northern Pike were removed from Lake 221. In 2012, despite intensive sampling efforts using baited minnow traps, fyke nets, trap netting, gill netting, angling, and visual observation, no forage fish of any species was observed or caught in Lake 110 or 221. In all three lakes where Northern Pike were added, prey fish populations were extirpated or too small to detect. In Lake 221, we estimated the current population of Northern Pike to be 49 ± 37, a 59% decrease since 2000 when prey fish were still present. The mean total length and body condition of Northern Pike in Lake 221 had not changed since the prey community collapsed. Our findings suggest that the introduction of Northern Pike into lakes without natural piscivore populations has long-lasting effects on fish community structure, to the detriment of both Northern Pike and prey fish populations.

Key Words: Invasive species; Esocidae; Northern Pike; *Esox lucius*; biomanipulation; food web manipulation; top predator invasions; top-down effects; Experimental Lakes Area; trophic cascade; fishery management

Introduction

Over the last few decades, numerous examples have made clear the threat that the introduction of non-indigenous species represents to aquatic ecosystem structure and function. Invasions by piscivorous fish tend to reduce the abundance and diversity of native fish species in lakes, a change that can cause a trophic cascade and have an impact on entire food webs (Ricciardi and MacIsaac 2011). Several instances have been documented of extreme reduction or extirpation of native fish populations in lakes following the introduction of Northern Pike (*Esox lucius*), a voracious top predator fish species (e.g., DeBates *et al.* 2003; Byström *et al.* 2007; Haught and von Hippel 2011). Predation by introduced Northern Pike has been associated with shifts in prey fish community structure from mainly small-bodied, soft-rayed species to deeper-bodied or spiny-rayed species (He and Wright 1992). However, few have reported the whole-scale elimination of the prey fish community (but see Haught and von Hippel 2011), as this is difficult to document (as opposed to measuring the presence of a very small population), and perhaps in part because it is unclear how long it takes a fish community to achieve an equilibrium state following top predator invasion.

At the Experimental Lakes Area (ELA) in northwestern Ontario, Northern Pike were introduced into three small Boreal Shield lakes with native fish communities consisting of only small species (Table 1). In 1987, Northern Pike were stocked in Lake 221 at 6.9 kg/ha (Findlay *et al.* 2005). The forage fish abundance was dramatically reduced within a year and remained low until 1994–95, when 85% of the Northern Pike were removed by gill net (Findlay *et al.* 2005). Northern Pike removal continued annually until 2000. By 1997, the lake's Yellow Perch (*Perca flavescens*) population had returned to pre-Northern Pike abundance and remained relatively constant until 2000, when monitoring ceased. Similarly, Northern Pike were stocked at 26 kg/ha in Lake 227 during 1993–1994, and the native cyprinid community was rapidly reduced (Elser *et al.* 2000). All of the Northern Pike were removed from the lake in 1996 following intensive gill netting over the summer period, and it has since been fishless (Elser *et al.* 2000; M. Rennie, personal communication). Finally, Northern Pike were added to Lake 110 during 1993–1994 to reach a density of 22.2 kg/ha by 1994 (see Elser *et al.* 1998). By 1995, the abundance of the lake's forage fish had decreased by more than 99%. Unlike Lakes 221 and 227, no Northern Pike were removed from Lake 110. Monitoring of Lake 110 ceased in 1997. The sub-

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A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalist's Club.

TABLE 1. Lakes in the Experimental Lakes Area, northwestern Ontario, Canada, where Northern Pike (*Esox lucius*) populations have been monitored.

Lake	Surface area, ha	Latitude, °N	Longitude, °W	Maximum depth, m	Years sampled
Introduced Northern Pike					
110	5.3	49.74367261	93.82192293	13.1	1992–1996
221	9.0	49.70127842	93.72678424	5.7	1987–2000, 2012
227	5.0	49.68769463	93.68883131	10.0	1992–2000*
Native Northern Pike					
191	19.4	49.57864433	93.77932348	4.0	1994–1995, 2001–2003†
222	16.4	49.69642947	93.72260758	5.8	2001–2003, 2012
239	54.3	49.66265402	93.72268920	30.4	1987–2012
240	44.1	49.65452497	93.72665578	13.1	1999–2012
658	8.4	49.73362146	93.73699463	13.0	1999–2012

*Surveys conducted in 1996–2000 revealed no evidence of fish in lake 227. Periodic surveys conducted in 2000–2010 confirmed the ongoing absence of fish, and no fish have been sighted during weekly visits to the lake for eutrophication research.
†Lake 191 was subject to macrophyte removal from 1996 to 1999. Years included for Lake 191 are only those before macrophyte removal and following recovery of the lake (K. Mills, M. Rennie, unpublished data).

sequent status of the fish communities in Lakes 221 and 110 was unknown until the current study was carried out in summer 2012.

Given the differences in endpoints reached by the prey fish communities at the cessation of monitoring in each of these Northern Pike-stocked ELA lakes (i.e., prey fish extirpated in Lake 227, low in abundance in Lake 110, and recovered to pre-Northern Pike abundance in Lake 221), we sought to determine the stability of the last known endpoints for prey fish communities in Lakes 110 and 221 by surveying their present-day fish communities, 19–25 years following biomanipulation. We sought to determine whether stocking Northern Pike in these lakes that lack natural piscivore populations would ultimately create a fish community structure comparable to that of nearby, similar lakes with naturally co-existing populations of Northern Pike and prey fish, or if we would find something akin to the observations in ELA Lake 227, where the native forage fish communities had been apparently extirpated.

An inability of predator-naïve forage fish to avoid predatory fish could lead to a post-Northern Pike-introduction fish community consisting of only Northern Pike and no prey fish or a "pike-only" lake (Patankar *et al.* 2006). Northern Pike are generally considered to be piscivorous fish that subsist on a diet of prey fish, but pike-only lakes do exist in Canada (e.g., Robinson and Tonn 1989; Beaudoin *et al.* 1999; Venturelli and Tonn 2006). Pike-only assemblages are thought to occur in small boreal lakes as a result of heavy piscivory by Northern Pike combined with winter hypoxia events that extirpate prey species less tolerant of harsh, low-oxygen conditions (Magnuson and Karlen 1970; Robinson and Tonn 1989). Winterkill has never been observed in ELA lakes, despite very low oxygen levels measured under ice in a number of lake systems that support cyprinids year to year (M. Rennie, personal communication). Northern Pike in pike-only lakes rely on invertivory and cannibalism, and because of low availability of high-quality food sources, tend to have slower growth (Venturelli and Tonn 2006) and potentially smaller mean or maximum body lengths (Huss *et al.* 2013) than Northern Pike in proximal lakes containing prey fish. We predicted that as prey densities became depleted in Northern Pike-stocked ELA lakes, we would find small populations of Northern Pike, with smaller average body size and poorer body condition than was previously seen, due to a lack of high-quality food sources.

Study Area

Lakes 110, 221, and 227 are small lakes located at the ELA (Table 1); they are geographically separated and hydrologically distinct from one another (3–10 km apart). Lakes 110 and 227 are headwater lakes; Lake 110 flows into a large wetland network before flowing into Lake 625. Lake 227 flows into Lake 305 via a 3-m waterfall. The physical barriers (waterfall, wetlands) make emigration from downstream water bodies to each of these lakes highly unlikely. Lake 221 is a second-order lake, connected upstream to Lake 220 by a small, intermittent, and ephemeral flow of water, and downstream via a large wetland network to Lake 262. As in the other lakes, the nature of these hydrologic connections make movement of fish across water bodies highly unlikely.

Methods

Survey of prey fish communities

We surveyed the fish communities of Lakes 110 and 221 in July 2012. To assess prey fish populations, we used the methods of Elser *et al.* (1998, 2000), so that the data would be comparable both temporally and between lakes. In each lake, we deployed 10 minnow traps baited with bread at fixed sites in the littoral (seven traps at ≤ 1 m depth) and pelagic zones (three traps at 2–12 m depth), and set a winged fyke net at a fixed site perpendicular to shore at 1 m depth. A small, winged trap net was also deployed at a fixed site in the littoral zone of Lake 221 (1.5 m depth). We sampled daily for five to seven consecutive days. Daily catch per unit effort of small fishes was estimated as the total number of fish captured by all gear divided by the number of sampling devices set.

In addition, fish communities were observed visually by snorkeling in various habitat types of each lake. Over the course of two days, we snorkeled along approximately 95% of the shorelines, 60–75% of littoral areas, and 10–30% of pelagic areas in Lakes 110 and 221. Sightings of Northern Pike, Yellow Perch, and cyprinids were recorded as present (i.e., sighted at least once) or absent (i.e., never sighted).

Nearby Lake 222 was used to evaluate the applied methods (e.g., confirm their ability to detect prey fish when present). Lake 222 has long-standing co-existing populations of Northern Pike, Yellow Perch, and minnows (Blacknose Shiners, *Notropis heterolepis*) and was the source of many of the Northern Pike added to Lakes 110, 221, and 227 (Elser *et al.* 1998; Findlay *et al.* 2005). Methods were identical to those described above, although we were unable to check the traps on the sixth day and assumed that the resultant catch on the seventh day was equally distributed over the two-day period. We snorkeled approximately 10% of Lake 222, mostly in littoral areas and stopped after the efficacy of the visual observation method (i.e., ability to detect fish in a lake where they are known to be present) was verified by numerous sightings of Northern Pike, Yellow Perch, and minnows.

Some fish species may be poorly adapted to dealing with Northern Pike predation. To determine the role that initial species assemblage may have played in the outcome of these Northern Pike introductions, we examined prey fish communities that also support Northern Pike among selected ELA lakes equal to or smaller than Lake 222, using reported relative abundance estimates from fishing surveys (Beamish *et al.* 1976; M. Rennie, P. Blanchfield, and K. Mills, unpublished data). Prey fish in these surveys were collected using a combination of minnow traps, Beamish-style trap nets, and small-mesh gill nets, during various surveys conducted between 1973 and 2012.

Assessment of Northern Pike populations

Northern Pike populations were assessed using mark-recapture methods with angling and short-set experimental gill nets (mesh size 15–50 mm; nets were set for 30 min. to 4 h). Captured Northern Pike were weighed, measured, tagged, and released. Handling mortality was recorded but infrequent (typically less than 1% of all fish captured).

We used the Chapman-modified Lincoln-Petersen method to estimate the population size of Lake 221 in 2012. The modification was applied to compensate for the small sample size, as few fish were captured. The Lincoln-Petersen method uses marking, releasing, and recapturing of animals to estimate the size of a closed population (i.e., no births or immigrants and no deaths or emigrants), assuming equal probability of catching any individual and no loss of markers or marked individuals during the sampling period (Pollock *et al.* 1990). Population densities in other lakes were estimated using the POPAN method in the program MARK (version 7.2; White and Burnham 1999), based on a fully time-dependent model in each lake. Small samples result in overestimates of population size; however, the Chapman modification can be applied to reduce bias and obtain an approximately unbiased variance (Pollock *et al.* 1990).

To determine whether stocking densities in these experiments may have been responsible for the response of prey fish communities, standing crops of endemic Northern Pike in ELA lakes were estimated for comparison with those reported from lakes where Northern Pike were introduced and with reports in the scientific literature. Standing crops for each seasonal sampling period in each lake were determined as the mean abundance divided by the mean body mass of Northern Pike. Seasonal standing crops were then averaged within a lake to provide mean standing crop estimates with an associated estimate of error. Northern Pike in these lakes were collected using a variety of methods, including angling, beach seines, and Beamish-style trap nets.

Northern Pike body condition was estimated as an indicator of environmental favorability (e.g., habitat conditions and prey availability) and physiological well-being (Blackwell *et al.* 2000) using Fulton's condition factor (K):

$$K = W \times L^{3} \times 10^{7}$$

Where W is the wet weight of the fish (g) and L is the fork length of the fish (mm); 10^7 is applied as a scaling constant. We selected a total length range of 400–500 mm to compare current and historic conditions and conditions across lakes. Although Fulton's condition factor provides an estimate of body condition based on the relation between a fish's length and weight (Nash *et al.* 2006), it makes the unrealistic assumption of isometric growth, which is rare in nature (Blackwell *et al.* 2000), and results in length-related bias when applied across a large size range of fishes (e.g., Rennie and Verdon 2008). Our selection of a specific length range for estimates of K helps reduce this bias. Where data permitted, mean total length (mm) and body condition of Northern Pike were compared between two periods (before 2001 and 2001–2013) and among lakes using two-factor ANOVA. Periods were selected to compare condition and mean length of Northern Pike in Lake 221 up to the end of previous monitoring with contemporary estimates and to permit comparisons with reference lakes. Where period (and the interaction between period and lake) was shown to be non-significant, single-factor ANOVA was used to compare variables among lakes. Significant differences among groups were determined using a post-hoc Tukey's HSD (honest significant difference) test with a type I error rate of $\alpha = 0.05$. Because this test tends to be conservative in assigning significance, differences with probabilities < 0.1 are also reported. Log- and square root-transformations were applied to help normalize residuals.

Results

Prey fish communities

No prey fish were caught or observed by any method during extensive sampling efforts employed in 2012 in either Lake 110 or 221. Implementing the same methods in Lake 222 resulted in regular daily catches of Yellow Perch and minnows and regular visual observations of both prey fish and Northern Pike while snorkeling and boating (Figure 1).

Prey species that were extirpated from ELA lakes following Northern Pike introduction included Northern Redbelly Dace (*Chrosomus eos*) in Lakes 110 and 227; Finescale Dace (*Phoxinus neogaeus*) in Lakes 110 and 227; Pearl Dace (*Margariscus margarita*) in Lakes 110, 221, and 227; Fathead Minnow (*Pimephales promelas*) in Lakes 110 and 227; Yellow Perch in Lake 221; Slimy Sculpin (*Cottus cognatus*) in Lake 110, and White Sucker (*Catostomus commersonii*) in Lake 110 (Table 2). In ELA lakes of comparable size, Northern Redbelly Dace, Finescale Dace, and Pearl Dace do not co-occur with Northern Pike. In contrast, other lakes of similar size do support populations of Fathead Minnow and Slimy Sculpin and many support Yellow Perch and White Sucker, co-occurring with Northern Pike (Table 2).

Northern Pike populations

Too few Northern Pike were captured to permit contemporary mark-recapture population estimates in Lake 110. Although only two Northern Pike were caught in Lake 110 during 2012, one was of juvenile size (< 100 mm), which indicated ongoing natural recruitment in the population. The population size of Northern Pike in 2012 for Lake 221 was estimated to be 49 ± 37 (Chapman-modified Lincoln-Petersen estimate ± 95% confidence interval), which represents a 59% decrease in the population since 2000.

Standing crops of Northern Pike in ELA lakes with native Northern Pike populations ranged from 2.0 to 10.3 kg/ha (Table 3). Northern Pike stocking density and current densities in Lake 221 were within this range, whereas stocking densities in Lakes 110 and 227 were twice the highest natural density estimated for ELA lakes (Table 3). The 2012 density of Northern Pike in Lake 221 was less than half that of the initial stocking density (Table 3).

Northern Pike body condition did not vary significantly with time in reference lakes (two-factor ANOVA, $F_{1,1194} = 0.13$, $P > 0.05$), nor was there any significant interaction between period and lake ($F_{5,1189} = 0.40$, $P > 0.05$). However, one-way ANOVA revealed significant differences in Northern Pike body condition among lakes ($F_{5,1194} = 52.46$, $P < 0.05$; Figure 2). Body condition of the introduced Northern Pike in Lake 221 was similar to that of native Northern Pike in Lakes 239 and 240, but higher than that of native Northern Pike in Lakes 191, 222 (the source of Northern Pike for Lake 221), and 658 (Figure 2).

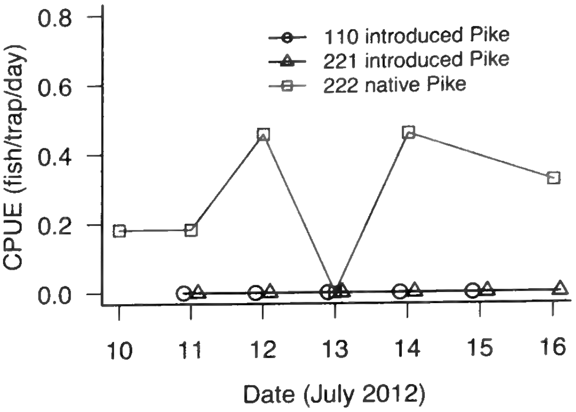

FIGURE 1. Relative prey fish catch per unit effort (CPUE) for Lakes 110, 221, and 222 in the Experimental Lakes Area, northwestern Ontario, using 10 minnow traps and one fyke net in each lake, plus one small trap net in Lake 221. Using these capture methods, no prey fish were detected in Lakes 110 and 221, where Northern Pike (*Esox lucius*) had been introduced. Offset on x-axis applied to data from lakes 110 and 221 to avoid visual overlap.

The mean size of Northern Pike varied by lake and period, (two-factor ANOVA, lake-time interaction, $F_{5,4532} = 10.79$, $P < 0.05$; Figure 3). Among our reference lakes, the mean body size of Northern Pike declined significantly in Lakes 191 and 222, and declines observed in Lake 240 were near significant (Figure 3). In contrast, body size was similar between periods in Lake 221 and in two reference lakes (239 and 658; Figure 3).

Discussion

In the ELA lakes, the introduction of Northern Pike into naïve prey fish communities has consistently, in three independent experiments, resulted in a major initial restructuring of those communities (Elser *et al.* 1998, 2000; Findlay *et al.* 2005) and, ultimately, as we have shown here, their apparent extirpation in these lakes. Although the extirpation of prey fish in Lake 227 was known before this study, it was thought that Lake 110 continued to support a remnant prey population and that Lake 221 continued to support Yellow Perch based on surveys conducted during 1995–2000. Our survey, more than a decade later, demonstrated otherwise.

Although the high stocking densities of Northern Pike used in Lakes 110 and 227 might provide an explanation for prey fish extirpation in these experiments,

TABLE 2. Relative abundance (A = abundant, M = moderate, R = rare) or intentional introduction (I) of fish communities in lakes smaller than 17 ha containing native or introduced Northern Pike (*Esox lucius*).

Lake characteristics and fish community					Native Northern Pike		Introduced Northern Pike*							
	190†	269†	383†	152‡	151‡	658‡	176‡	695†	70‡	265†	222†	110‡	221†	227†
Surface area, ha	5	5	5	5.3	6.5	8.4	9.7	10	11	13	16	5	7	5
Maximum depth, m	6	6	9	6.1	4.2	13.5	3.6	5	3.5	19	6	13	6	10
Esocids														
Northern Pike (*Esox lucius*)	A	A	R	M	M	A	M	M	M	A	A	I	I	I
Coregonids														
Lake whitefish (*Coregonus clupeaformis*)						M								
Cisco (*Coregonus artedii*)						R								
Catostomids														
White Sucker (*Catostomus commersonii*)		A		M	M	M	M	R	M	A	R	M		
Cyprinids														
Northern Redbelly Dace (*Chrosomus eos*)												M		A
Finescale Dace (*Phoxinus neogaeus*)												A		R
Golden Shiner (*Notemigonus crysoleucas*)	R	R						A						
Blackchin Shiner (*Notropis heterodon*)		R									A			
Blacknose Shiner (*Notropis heterolepis*)	M	A	A			M		A		R				
Spottail Shiner (*Notropis hudsonius*)			A											
Fathead Minnow (*Pimephales promelas*)						R		A		R		M		A
Pearl Dace (*Margariscus margarita*)												A	M	A
Cods														
Burbot (*Lota lota*)						R					R			
Centrarchids														
Rock Bass (*Ambloplites rupestris*)	R													
Pumpkinseed (*Lepomis gibbosus*)	M	R					M	M						
Percids														
Yellow Perch (*Perca flavescens*)	M	A	A	M		A	A	M			A		M	
Walleye (*Sander vitreus*)							M							
Iowa Darter (*Etheostoma exile*)								R		R				
Sculpins														
Slimy Sculpin (*Cottus cognatus*)						R				R		M		

*Relative abundance of fishes is based on data collected before introduction of Northern Pike.

†Reproduced from Beamish *et al.* 1976.

‡Not reported in Beamish *et al.* 1976; generated from surveys conducted using similar methods, 1984–2000.

TABLE 3. Standing crop of Northern Pike (*Esox lucius*) in some lakes of the Experimental Lakes Area, northern Ontario, Canada.

Lake	Standing crop, mean ± standard deviation, kg/ha*
Introduced Northern Pike	
110	22.2
221 (1987-2000)	6.9
221 (2012)	2.8 ± 4.2
227	26.0
Native Northern Pike	
191	10.3 ± 2.2
222	8.7 ± 3.5
239	2.0 ± 0.8
240	4.5 ± 1.1
658	8.5 ± 2.3

*Means with standard errors are based on multiple seasons of observation. Error for 2012 densities in Lake 221 is based on the error of products (standard deviation in abundance estimates and in mean weight in kg [Ku 1966]). Values without error are calculated from known stocking densities and individual weights of fish stocked, as reported in the original source: Lake 110, Elser *et al.* 1998; Lake 221, Findlay *et al.* 2005; Lake 227, Elser *et al.* 2000.

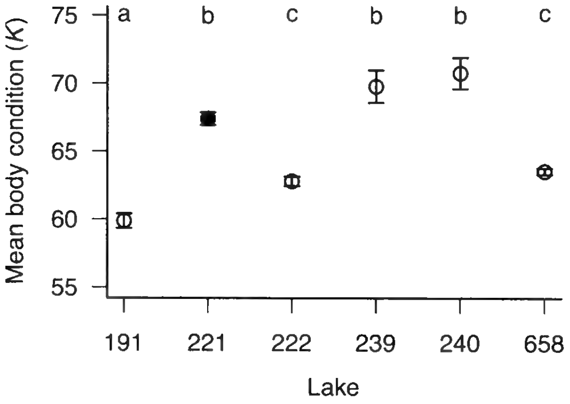

FIGURE 2. Mean body condition (Fulton's condition factor × 10^7 ± standard error) of Northern Pike (*Esox lucius*), 400–500 mm in fork length, from lakes in the Experimental Lakes Area, northwestern Ontario, 1987-2012. Pike were introduced into Lake 221 (shaded symbol), but were indigenous in the other lakes (open symbols). Years sampled in each lake are reported in Table 1. Means with different letters are significantly different (Tukey's, $P < 0.05$).

this is likely not the case in Lake 221. In Lake 221, stocking density was within the range of natural standing crops of Northern Pike in similar-sized ELA lakes (Table 3). In Lakes 110 and 227, Northern Pike were added at approximately twice the density of the highest reported standing crop in an ELA lake (Table 3), but comparable to densities of Northern Pike reported elsewhere (Table 4).

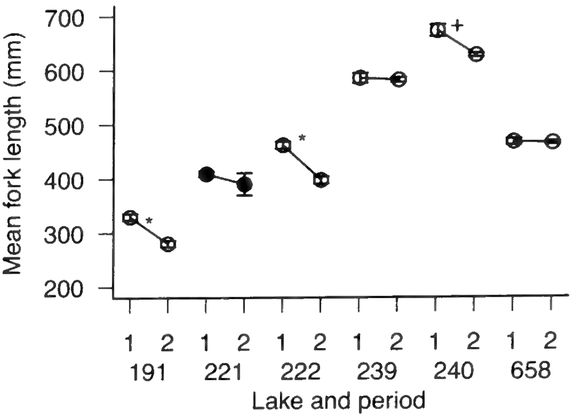

FIGURE 3. Mean fork length (mm ± standard error) of Northern Pike (*Esox lucius*) in lakes of the Experimental Lakes Area, northwestern Ontario, between 1987-2000 (period 1) and 2001-2013 (period 2). Pike were introduced into Lake 221 (shaded symbol), but were indigenous in the other lakes (open symbols). Years sampled in each lake are reported in Table 1. *Significant difference between years at $P < 0.05$ level; + $P < 0.1$.

Of note is the duration of time required for these lakes to become "pike-only." Although this point appears to have been reached only four years after the introduction of Northern Pike into Lake 227, prey fish populations persisted at detectable levels three years after stocking of Northern Pike in Lake 110 (Elser *et al.* 1998) and 13 years after stocking in Lake 221 (Findlay *et al.* 2005). Although it is unclear exactly how long it took for these lakes to become devoid of prey fish, other studies suggest that extinction of prey communities takes upward of a decade following Northern Pike invasion (Haught and von Hippel 2011); our data from Lakes 110 and 221 are consistent with this timeline. Pond-based studies have demonstrated that predator-naïve Fathead Minnows are capable of learning appropriate prey responses to Northern Pike within 4–10 days (Brown *et al.* 1997; Chivers and Smith 1995). However, our work and that of others (Haught and von Hippel 2011) suggest that this learned response may be insufficient to guarantee persistence of naïve prey populations in the long term.

Few other studies report an extirpation of the entire prey fish community following Northern Pike introduction, as was observed in these three ELA lakes. Northern Pike addition 200 years ago resulted in a pike-only community in Lake Myravatn, Norway, until the addition of Yellow Perch in 2006 (Regmi 2012). However, it is also worth noting that none of Lakes 110, 221, or 227 contained endemic piscivore species before Northern Pike introduction, which may make their fish communities particularly ill adapted to respond appropriately to a novel fish predator (Sih *et al.* 2010).

The extirpation of prey fish from Lakes 110, 221, and 227 was likely due to a combination of both the prey community composition in those lakes and prey naïvety. Cyprinids, in particular, appear to be highly vulnerable to Northern Pike introduction. Small fish

TABLE 4. Summary of published reports of Northern Pike (*Esox lucius*) standing crops.

Lake	Standing crop, kg/ha	Surface area, ha	Northern Pike introduced?	Reference
Chew Valley Lake	3.3	490	Y	Ibbotson and Klee 2002
Lake Lyng	5.2*	10	Y	Berg *et al.* 1997
Slapton Ley	22.5	90	N	Bregazzi and Kennedy 1980
West Long Lake	22.0	25	Y	DeBates *et al.* 2003
Windermere	9.5	1473	N	Kipling and Frost 1970

*Estimate derived from sum of reported annual stocking densities and approximation of mean mass of stocked fishes (assumed 3 g each).

are typically more susceptible to predation (Tonn *et. al.* 1992) because of size-selective feeding and gape-limitation in piscivores (Tonn and Paszkowski 1986; Post and Evans 1989), although both body size and morphology contribute to predation risk (He and Kitchell 1990). In Lake 221, Pearl Dace were apparently extirpated within two years of Northern Pike additions, and all four minnow species were eliminated from Lake 227 within three years. Lakes with naturally occurring Northern Pike from similar-sized lakes in the ELA do not appear to support Northern Redbelly Dace (extirpated from Lakes 110 and 227), Finescale Dace (extirpated from Lakes 110 and 227) or Pearl Dace (extirpated from all three lakes where Northern Pike were introduced; Table 2). However, White Sucker (extirpated from Lake 110) naturally co-occurs with Northern Pike in nine of 11 lakes of similar size in the ELA, and Yellow Perch (extirpated from Lake 221) naturally co-occurs with Northern Pike in eight of 11 lakes (Table 2). Fathead Minnow (extirpated from Lake 227) naturally co-occurs with Northern Pike in three of 11 lakes, and other Northern Pike lakes commonly support other minnow species, most notably Blacknose Shiner (six of 11 lakes). This pattern is generally supported by other studies. Among Adirondack lakes ranging in size from 0.1 to 140 ha, Northern Redbelly Dace and Pearl Dace were typically absent from lakes containing Northern Pike and other top piscivores (Findlay *et al.* 2000). Similarly, Algonquin lakes containing Northern Pike and other top predators were typically negatively associated with Finescale Dace, Northern Redbelly Dace, and Fathead Minnow (Trumpickas *et al.* 2011). The more frequent co-occurrence of Yellow Perch compared with minnows may be partly due to morphological differences, i.e., the spiny rays of Yellow Perch may afford it greater protection from predators (Willman 2007) than the soft rays of minnows. Habitat use may also play a role, as cyprinids appear especially sensitive to exclusion in the presence of predominantly littoral predators, such as Northern Pike or Smallmouth Bass (*Micropterus dolomieu*) (Robinson and Tonn 1989; Whittier *et al.* 1997).

Previously reported biomanipulation studies have described major changes in fish communities due to Northern Pike addition, including extirpations of specific prey fish species. The addition of small Northern Pike to a shallow Polish lake for four years resulted in near failure of recruitment of Roach (*Rutilus rutilus*) and White Bream (*Blicca bjoerkna*), due to intense predation on small-bodied fishes, and near-extirpation of Belica (*Leucaspius delineatus*) (Prejs *et al.* 1994). Dramatic reductions in Yellow Perch and White Sucker in lakes in the United States have been associated with recruitment failure in these species following Northern Pike addition (Colby *et al.* 1987; DeBates *et al.* 2003). Conversely, Yellow Perch and White Sucker increased in abundance following the removal of Northern Pike from Harriet Lake, USA (Colby *et al.* 1987). Bluegill (*Lepomis macrochirus*) in West Long Lake, USA responded positively to a reduction in Northern Pike biomass by approximately 50%, but Yellow Perch did not (Jolley *et al.* 2008).

We do not believe that our inability to detect prey fish in Lakes 110 and 221 following Northern Pike addition is a result of prey behavioural response to predation. Although predator introduction may induce behavioural changes in forage fish (i.e., hiding) that may make them more difficult to catch or observe (Kidd *et al.* 1999), we employed extensive passive and active sampling methods in these lakes — the same methods that proved effective in our reference Lake 222 (Figure 2), where both Northern Pike and prey fish were present.

Given that many ELA lakes have endemic populations of both Northern Pike and prey fish, the ultimate outcome of the Northern Pike additions in the ELA that we report here may be that, in lakes without natural piscivore populations, prey fish lack effective predator avoidance behaviour and may be unable to adapt quickly enough to avoid being extirpated by novel forms of fish predation. Numerous previous studies have demonstrated that prey naïve to predators may respond differently to predation compared with experienced prey (Sih *et al.* 2010). Sufficient variation in predator-avoidance behaviours may be lacking among forage fish in lakes without endemic piscivores (which may have been lacking piscivore-related selection pressure since the last glaciation in this region) to generate an appropriate predator response, leaving them ill equipped to deal with introduced predators. Our study suggests that minnows are likely most sensitive to extirpation versus non-cyprinid forage fish species, such as Yellow Perch, as evidenced by the rapid disappearance of minnows in Lakes 110 (Elser *et al.*

1998), 221 (Findlay *et al.* 1994), and 227 (Elser *et al.* 2000) following Northern Pike introductions. Similar interactions between naïve prey communities and introduced predators may be occurring elsewhere; for instance, as Smallmouth Bass expand their Canadian range northward with a warming North American climate (Sharma *et al.* 2009).

We found no significant changes in fish condition between periods for Northern Pike in any of our reference lakes or in manipulated Lake 221. Body condition of Northern Pike in Lake 221 (where they were introduced) was relatively high compared with that in reference Lakes 222 and 658, but was comparable with that in reference Lakes 239 and 240. Juvenile Northern Pike can easily survive on invertivory alone, but inadequate access to high-quality food (e.g., forage fish) tends to limit the growth of adult Northern Pike (Venturelli and Tonn 2006). The stability of Northern Pike body condition in the face of a collapse of their prey base can likely be explained by two related factors. First, the biomass of Northern Pike in Lake 221 was less than half the density it was when the prey population was present, indicating a significant reduction in intraspecific competition. Second, Northern Pike are well known to exhibit cannibalism (Venturelli and Tonn 2006 and references therein). Not only does this act to further limit intraspecific competition, but it also provides larger food items that can facilitate more efficient feeding and elevated body condition.

Our study provides insights as to the direction of future research to determine the role of Northern Pike in these small-lake food webs and the cause of prey fish extirpation following Northern Pike introductions. A stable isotope study comparing multiple trophic levels, including fish, zooplankton, and invertebrates before and after Northern Pike introduction (and following prey extirpation) would generate a clearer picture of how pathways of energy transfer have changed in these lakes. Further ongoing efforts to collect Northern Pike from Lakes 110 and 221 will provide an opportunity to compare growth rates under current (prey-absent) conditions versus growth rates when prey were present, as well as versus those in reference lakes, and better ascertain current Northern Pike densities in Lake 110. On the basis of our findings, we recommend behavioural experiments to examine the susceptibility and behavioural plasticity of small-bodied fish species that are common in lakes both with and without top-predator fish (e.g., Yellow Perch, White Sucker) to better understand the reason for their elimination from the lakes in our study, but common co-occurrence with Northern Pike in many other instances. The potential capability of predatory fishes to drive whole prey fish communities to extirpation, as observed in our studies and suggested by the work of others (e.g., Whittier *et al.* 1997), underlines the importance of implementing more effective controls on the further dispersal of predatory fish species (e.g., Sharma *et al.* 2009; Haught and von Hippel 2011) to preserve the diversity of fishes in small lakes lacking native predators.

Acknowledgements

We thank the following people for assistance with data collection and study design: Mike Paterson, Al Dupuis, Paul Blanchfield, Amy Gilbert, Bailey Rankine, Lindsay Furtado, Brendan Allan, Jon Martin, AJ Chapelsky, David Callaghan, Colin Charles, Matt Guzzo, Dan Abrahamson, and Sandy Chalanchuk. We thank Beth Cheever, Scott Higgins, Rick Baydack, and Paul Venturelli who provided thoughtful comments that helped to improve this manuscript. An earlier draft of this manuscript was improved by the comments of two anonymous reviewers.

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Received 28 October 2014
Accepted 5 May 2015

Status, Distribution, and Nomenclature of Northern Quillwort, *Isoetes septentrionalis* (Isoetaceae), in Canada

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Brunton, Daniel F., and John McNeill. 2015. Status, distribution, and nomenclature of Northern Quillwort, *Isoetes septentrionalis* (Isoetaceae) in Canada. Canadian Field-Naturalist 129(2): 174–180.

The lycophyte Northern Quillwort (*Isoetes septentrionalis* D. F. Brunton, *sp. nov.*) is the northern component of the Riverbank Quillwort (*I. riparia*) complex. It is locally abundant in southeastern Ontario and southwestern Quebec and is also widely distributed in the northeastern United States. In Canada, it is largely confined to river and lake shores along post-glacial drainage outlets within the limits of the post-glacial Champlain Sea. It is frequently found in association with other *Isoetes*, especially Dodge's Quillwort (*I.* ×*dodgei* A. A. Eaton), its sterile hybrid with Spiny-spored Quillwort (*I. echinospora* Durieu). The Canadian population of *I. septentrionalis* appears to be stable. Although first proposed at species level over a century ago, the nomenclature of this taxon has remained unresolved. It is clarified in the present study, in which *I. canadensis* var. *robbinsii* is lectotypified.

Key Words: Riverbank Quillwort; Northern Quillwort; *Isoetes septentrionalis*; *Isoetes riparia*; *Isoetes* ×*dodgei*; *Isoetes canadensis* var. *robbinsii*; Champlain Sea

Introduction

The Riverbank Quillwort, *Isoetes riparia* Engelmann ex A. Braun (Isoetaceae) complex consists of a number of tetraploid ($2n = 44$) aquatic emergent lycophytes (fern allies) that occur widely across eastern North America. *Isoetes riparia* (*s.l.*) is found predominantly close to and along the Atlantic Coastal Plain north from Virginia into southern Maine and then inland along major river and lake systems through eastern New England into the Champlain Sea lowlands of northern New York, southeastern Ontario, and southwestern Quebec (Taylor *et al.* 1993). It is typically uncommon to rare (Montgomery and Fairbrothers 1993; Tryon and Moran 1997; Taylor and Brunton 2000; Gerke *et al.* 2014). Although possibly more abundant within its Canadian rather than its adjacent United States range, it is considered a species of conservation concern in Ontario (Oldham and Brinker 2009) and potentially also in Quebec (Cody and Britton 1989).

Isoetes riparia (*s.l.*) is a complex taxon with a tangled nomenclatural history (Engelmann 1882; Eaton 1903a; Pfeiffer 1922; Proctor 1949; Kott and Britton 1983). Northern (typically inland) freshwater populations of robust plants (Figure 1) characterized by larger, more coarsely ornamented megaspores have been variously referenced as *I. riparia, I. dodgei* A. A. Eaton (as a species, not as a hybrid) and *I. canadensis* (Kott and Britton 1983; Britton and Brunton 1989). In at least parts of Canada, for many years *I. riparia* (*s.l.*) populations were also confused with the decaploid ($2n = 110$) *I. lacustris* Linnaeus (*I. macrospora* Durieu) (e.g., Marie-Victorin 1935; Boivin 1966; Gillett and White 1978). Kott and Britton (1983) clarified the differentiation of *I. lacustris* from *I. riparia* (*s.l.*), noting especially the much larger megaspores of the former species, which also exhibit a more evenly reticulate ornamentation pattern. The identification of *I.* ×*jeffreyi* D. M. Britton & D. F. Brunton as the sterile, septaploid ($2n = 77$) hybrid between *I. lacustris* and northern *I. riparia* (*s.l.*) confirmed the distinction between these two species (Britton and Brunton 1992). For working purposes, the distinctive northern component of *I. riparia* (*s.l.*) has been known as *I. riparia* "canadensis" and will initially be so referenced in the following.

FIGURE 1. Mature, emergent plants of *Isoetes septentrionalis*, Madawaska River, Stewartville, Renfrew County, Ontario, Canada, 25 July 2013. Photo: D. F. Brunton.

Southern *Isoetes riparia* (*s. str.*) (*I. saccharata* Engelmann, including *I. riparia* var. *reticulata* (A. A. Eaton) Proctor) occurs in shallow brackish water and emergent tidal shores along the Atlantic coastal plain (Proctor 1949). The holotype of *I. riparia* ("gravelly shore, Dela-

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A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalist's Club.

ware River near Philadelphia, Dr. Zantziger August 1844," MO) is from near the northernmost limit of the range of *I. riparia* (*s.str.*). The *I. riparia* complex is also considered to include the recently described freshwater aquatic *I. hyemalis* D. F. Brunton as its southernmost component (Caplen and Werth 2000a).

The distinction between the northern "canadensis" component of *Isoetes riparia* (*s.l.*) and the complex of southern components has been recognized for many years (Engelmann 1882; Clute 1904; Pfeiffer 1922). In addition to previously documented morphological and ecological differences, however, the investigation of *I. riparia* (*s.l.*) isozyme genotypes by Caplen and Werth (2000a, 2000b) provided strong evidence for the uniqueness of the northern "canadensis" taxon as an allopolyploid species arising from hybridization between the diploids ($2n = 22$) *I. echinospora* and *I. engelmannii* A. Braun. In contrast, they determined that southern *riparia* complex components most likely arose from different diploid ancestors, including *I. valida* (Engelmann) Clute, *I. mattaponica* L. J. Musselman & W. C. Taylor and *I. flaccida* A. Braun.

The following provides a review of the Canadian status of *Isoetes riparia* "canadensis" to evaluate its apparent relative abundance, identify distribution patterns, and report and evaluate recent additions to its previously known range. With the added weight of genetic evidence supporting long-standing arguments for this taxon to be treated at species level, the need for nomenclatural clarification is compelling. That clarification is provided below.

Methods

Observations on the ecological characteristics of *Isoetes riparia* "canadensis" were developed during field investigations conducted by the first author throughout the range of *I. riparia* (*s.l.*) since 1987. Distributional information and the physical attributes of preserved specimens were determined through the examination of over 300 voucher specimens in CAN, DAO, DUKE, FLAS, FSU, MB, MICH, MO, NYS, OAC, PH, PSU, TRT, UNA, US and the D. F. Brunton personal herbarium. Approximately 125 of these were from *I. riparia* "canadensis" populations. Scanning electron microscope (SEM) images and the cytology of a selection of these specimens were obtained by the late D. M. Britton of the University of Guelph, employing the techniques described in Britton and Brunton (1989, 1992).

Results and Discussion

Nomenclature

Most confusion over the existing nomenclature of Canadian *Isoetes riparia* (*s.l.*) arises from George Englemann's (1882) speculative application of "canadensis" as a working hypothesis. He suggested that northern populations, "*might be* [emphasis ours] designated as var. *Canadensis* [sic], but too little is known about it as yet to form a definite opinion." This does not satisfy the requirements for valid publication, the name being "merely proposed in anticipation of the future recognition of the taxon" (McNeill *et al.* 2012: Article 36.1(b)). Engelmann (1882) cited two specimens that are morphologically and distributionally attributable to the northern component of *I. riparia* (*s.l.*). This account provided a weak but nonetheless nomenclaturally acceptable description of their distinction from the rest of the *I. riparia* complex: "with very few stomata on the leaves and apparently two weak bast-bundles, an upper and a lower one, very pale spots on the sporangia and smoothish microspores."

No further review of this complex occurred until 1898 when Alvah Eaton described *Isoetes dodgei* A. A. Eaton as a new species, close to but distinct from Engelmann's "canadensis" (Eaton 1898). Nonetheless, within a few years he revised that concept (Eaton 1901), concluding that Engelmann's "canadensis" warranted treatment at the species level and proposing "*Isoetes canadensis* (Engelmann) A. A. Eaton, *comb. nov.*" In fact, because Engelmann had not validly published the supposed basionym, this is not a new combination but publication of a new species, validated by Engelmann's brief description. In publishing this new species, however, Eaton also placed his recently described *I. dodgei* in synonymy under *I. canadensis*. Without designating a type from which to unequivocally distinguish "canadensis" from *I. dodgei*, *I. canadensis* thus became a nomenclatural synonym of the previously described *I. dodgei* (McNeill *et al.* 2012: Article 7.5). Eaton soon appreciated this himself, and acknowledged that nomenclatural priority rules prescribed the use of *I. dodgei* over *I. canadensis* (Eaton 1908).

The name *Isoetes dodgei* (and thus *I. canadensis*) was lectotypified by Kott and Britton (1983). Britton and Brunton (1989) subsequently established that most *I. dodgei* specimens, including the lectotype, represent the triploid hybrid *I. echinospora* × *I. riparia* Engelmann (*s.l.*). It was accordingly revised to *I.* ×*dodgei* A. A. Eaton, *pro. sp.* (Britton and Brunton 1989), the hybrid taxon to which the name *I. canadensis* applies as a synonym. The *I. riparia* of Britton and Brunton (1992) is the *I. riparia* "canadensis" taxon discussed here.

Pfeiffer's (1922) "var. *canadensis* Engelmann" published under *Isoetes riparia*, while constituting the first valid publication of *I. riparia* var. *canadensis* Engelmann ex Pfeiffer, is also illegitimate because Pfeiffer included *I. canadensis* var. *robbinsii* A. A. Eaton (Eaton 1903b) in synonymy. She thus should have adopted the latter, previously published, epithet. As Pfeiffer also included *I. canadensis* A. A. Eaton in the synonymy of *I. riparia* var. *canadensis*, she definitely indicated a different type (that of *I. canadensis* = *I.* ×*dodgei*) from that of *I. canadensis* var. *robbinsii* (McNeill *et al.* 2012: Article 7.5 and example 6). *Isoetes canadensis* var. *robbinsii* A. A. Eaton (*I. dodgei* var. *robbinsii* (A. A. Eaton) A. A. Eaton in Eaton (1908) and *I. riparia* var. *robbinsii* (A. A. Eaton) Proctor in Proctor (1949)) has been shown to have been applied to both *I.* ×*novae-angliae* D. F. Brunton & D. M. Britton (the sterile tetraploid hybrid *I. riparia* "canadensis" × *I. tuckermanii* A. Braun) and *I. riparia* "canadensis" (Brunton and Britton 2006). To eliminate this ambiguity with "robbinsii," we designate here the following as lectotype for *Isoetes canadensis* var. *robbinsii* A. A. Eaton (Eaton 1903b: 279): UNITED STATES. MASSACHUSETTS. Watson's Pond, Taunton, 15 September 1905, *A. A. Eaton 308,* MICH ex herb A. A. Eaton [middle plant (*I.* ×*novae-angliae*) on mixed sheet between two *I. septentrionalis* plants (to left) and two *I. tuckermanii* plants (to right)]; sheet labeled "Type" in Eaton's handwriting. In this way the various varietal names with the epithet "*robbinsii*" become synonyms of *I.* ×*novae-angliae*.

The previously described taxonomic and nomenclatural confusion surrounding *Isoetes riparia* "canadensis" was due in large measure to the existence of undetected sterile hybrids, which present ambiguous, intermediate morphological characteristics. Until the nature of such hybrids was recognized in the *I. riparia* complex (Britton and Brunton 1989, 1992), the misinterpretation of hybrids often contributed to the presentation of conflicting taxonomic interpretations.

This analysis of the complex nomenclatural history of the northern "canadensis" component of the *Isoetes riparia* complex indicates that no validly published name is available for it at species level. Accordingly, the following is proposed.

Isoetes septentrionalis* D. F. Brunton**, ***sp. nov. (Figures 1 and 2). TYPE: CANADA. ONTARIO. City of Ottawa, 45.373850°N, 75.788695°W, 250 m east of water purification plant along south shore of Ottawa River, Britannia Conservation Area, 26 July 1998 *Daniel F. Brunton 13 646* (Holotype: OAC; Isotypes: ODU, FSU, D. F. Brunton personal herbarium). The epithet "septentrionalis" refers to the northernmost geographic position of this species within the *I. riparia* complex.

The species has previously been recognized under the following names, none of which correctly apply to it: *Isoetes riparia* "var. *canadensis* Engelmann" (Engelmann 1882); *I. canadensis sensu* Eaton (1901, 1903a, 1903b) *pro parte*, *non I. canadensis* A. A. Eaton; *I. riparia* var. *canadensis sensu* Pfeiffer (1922) *pro parte*, *non I. riparia* var. *canadensis* Engelmann ex Pfeiffer; *I. riparia* Engelmann f. *canadensis sensu* Proctor (1949) *pro parte*, *non I. riparia* f. *canadensis* Proctor. (The type of all the names with the epithet "canadensis" is referable to *I.* ×*dodgei* (*I. echinospora* × *I. septentrionalis*).)

HABIT: Short (< 25 cm tall), aquatic and emergent plant arising from a rounded, two-lobed corm 0.75–1.7 cm wide; LEAVES: simple, erect to recurved, semi-evergreen, gradually tapering to the tip, shiny to (usually) dull olive green with sporangia inset into the inner side of widened, whitish-green to white bases; SPORANGIA: brown-streaked to completely brown with velum covering 25–40% of sporangium wall; MEGASPORE: round, about 545 µm (343–682 µm [720 µm], Kott and Britton 1983) in diameter, triradial hemisphere with a pattern of short, broken to loosely anastomosing ridges and with spines frequently occurring along the ridges (Figure 2a), distal hemisphere with an open pattern of short, irregular, loosely anastomosing ridges and no equatorial band of spines (Figure 2b); MICROSPORES: white to grayish in mass, round to oval, about 31 µm (24–38 µm [42 µm], Kott and Britton 1983) in length with numerous tubercles on a smooth perispore (Figure 2c); CYTOLOGY: $2n = 44$ (Kott and Britton 1983; Britton and Brunton 1989; Britton and Brunton 1992).

PARATYPES:

CANADA. ONTARIO. Hastings County: Canada West, Crow [sic] River, *J. Macoun s.n.*, 18 July 1864 (MO); 44.49036°N, 77.68920°W, 620 m west of Iron Works dam ruins along east shore of Crow [sic] River, Marmora, 24 September 2002, *D. F. Brunton 15 341* (OAC, TTC, CAN, D. F. Brunton personal herbarium); Leeds & Grenville County: Champagne Point, Thousand Islands, 23 September 1908, *E. P. Bicknell 11 393* (NYS); Renfrew County: 46.17171°N, 77.62674°W, Meilleurs Bay by Highway 17 rest stop near Rolphton, Laurentian Hills,16 August 2007, *D. F. Brunton 17 078* (D. F.

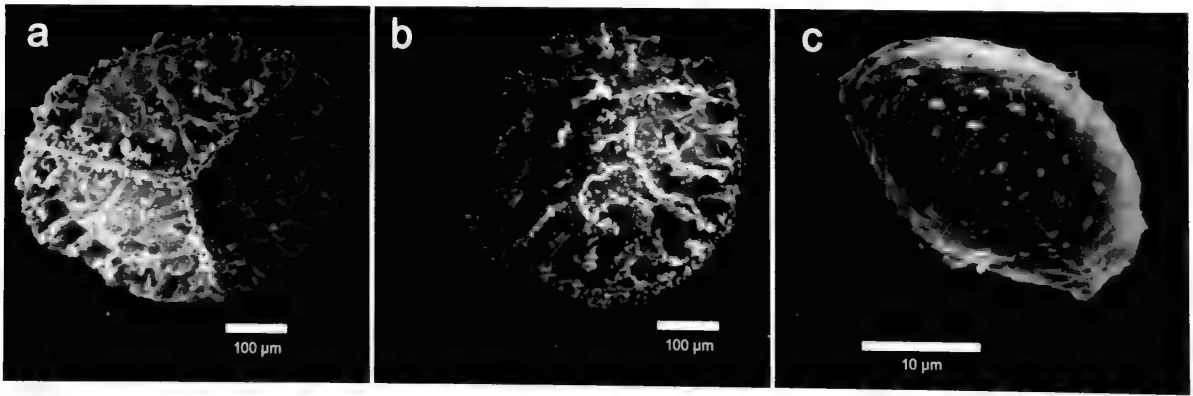

FIGURE 2. Spores of *Isoetes septentrionalis*: (a) triradial hemisphere of megaspore (*J. A. Calder and W. J. Cody 1,685*, 9 September 1947, Fitzroy Harbour, Ontario, DAO); (b) distal hemisphere of megaspore (*L. and E. Kott 622a*, 19 August 1978, Fitzroy Harbour, Ontario, OAC); (c) microspore (*L. and E. Kott 622a*, 19 August 1978, Fitzroy Harbour, Ontario, OAC).

Brunton personal herbarium); [45.3061°N, 76.7108°W], shore of Calabogie Island, Calabogie, Madawaska River, 24 July 1990, *W. D. Bakowsky s.n.* (D. F. Brunton personal herbarium); QUEBEC. Comté de Pontiac: [45.834°N, 76.751°W], Rive de la rivière des Outaouais, sud-ouest de Fort-Coulonge, 3 September 1997, *M. Blondeau et M. J. Oldham OUT-013* (QFA); Gatineau County: [45.38755°N, 75.79421°W] 1 km below Deschênes Rapids, Aylmer, 12 September 1988, *D. F. Brunton 8629* (OAC) [determined $2n = 44$, D. M. Britton, 1988]; UNITED STATES. CONNECTICUT. Fairfield County: mill race in Mill River, Fairfield. *E. H. Eames 8624*, 8 September 1912 (NY); MASSACHUSETTS. Barnstable County: Watson's Pond, Taunton. *A. A. Eaton s.n.*, 15 September 1903 (MICH); NEW HAMPSHIRE. Grafton County: [Powow Pond, Powow River], Kingston, *A. A. Eaton 942*, September 1897 (MICH); NEW JERSEY. Morris County; in Passaic River near Pompton Plains. *R. W. Storer 380*, 30 August 1939 (MICH); NEW YORK. Washington County: along Hudson River, town of Easton. *H. D. House 23,885*, 26 August 1936 (PH); PENNSYLVANIA. Lycoming County: 41.20250°N, 77.25166°W, Susquehanna River below and beside the Main Street Bridge, Jersey Shore, 6 July 1992, *Daniel F. Brunton and Karen L. McIntosh 11 179* (OAC, MIL, D. F. Brunton personal herbarium) [sampled for analysis in Caplen and Werth 2000a, 2000b]; VERMONT. Caledonia County: Comerford Reservoir near Waterford town line, Barnet, 3 August 1993, *A. V. Gilman 93-189* (MICH). At least one representative paratype is identified for all states and provinces in which the species occurs, except Maine and Rhode Island from which no specimens were seen.

The following modification of a portion of the *Isoetes* key in the Flora of North America (FNA) treatment (Taylor *et al.* 1993) is provided to assist in the identification of *I. septentrionalis* specimens. A couplet addressing *I. septentrionalis* is inserted in that portion of the key treating aquatic, eastern North American *Isoetes* that do not possess echinate megaspores and have velum coverage over less than half of their sporangia. The numbering of the otherwise unaltered 1993 FNA key is retained to simplify comparison. The term "girdle" in the key is equivalent to "equatorial band" used in this paper.

10. Megaspores averaging less than 500 μm diameter; reticulate with unbroken lamellate ridges . . . *Isoetes engelmannii*

10. Megaspores averaging more than 500 μm diameter; reticulate, rugulate, or cristate with isolated broken ridges.

11. Megaspores with densely papillate or smooth girdle; leaves olive green to reddish-brown.

12. Megaspores with densely papillate girdle, reticulate to cristate with ridges having irregular and roughened crests . . . . *Isoetes tuckermanii*

12. Megaspores with smooth girdle, rugulate to reticulate with ridges having rounded and smooth crests . . . . *Isoetes acadiensis*

11. Megaspores with obscure girdle; leaves bright green.

13. Megaspores cristate with isolated and branching lamellate ridges; plants of northeastern North America and eastern seaboard.

13A. Megaspores with short, broken to loosely anastomosing ridges; no equatorial band of spines; freshwater habitat . . . . *Isoetes septentrionalis*

13B. Megaspores with densely crowded (rarely, low and broad), anastomosing ridges; equatorial band of spines obscure to conspicuous; tidal beach habitat . . . . *Isoetes riparia* (*s.str.*)

Distribution and Status in Canada

As noted above, *Isoetes septentrionalis* occupies the northernmost geographic position of any component of the *I. riparia* complex. In Canada, Cody and Britton (1989) identify *I. septentrionalis* (as *I. riparia*) as occurring in the lower Ottawa River valley of Ontario and Quebec from Ottawa, Ontario, and Gatineau, Quebec, downstream for approximately 200 km to Montreal, Quebec, and downstream along the St. Lawrence River for another approximately 100 km to Sorel. Outliers are known inland in Ontario in the Tweed–Marmora area of Hastings County (approximately 150 km west of the Ottawa River) and along the St. Lawrence River in Leeds & Grenville County (180 km upstream from Montreal). Sites away from the St. Lawrence River in Quebec include the north end of Lake Champlain (approximately 50 km south of the river) and the Thetford Mines area of the Eastern Townships (approximately 65 km southeast of the river).

Our knowledge of the distribution of *Isoetes septentrionalis* in Canada has expanded in the last 20 years, notably in and about the Ottawa Valley of Ontario and Quebec (Figure 3). Recent discoveries have extended its known range more than 100 km upstream along the Ottawa River. As noted in Figure 3, these include the Pontiac County, Quebec, population supported by specimens from Fort Coulonge (*M. Blondeau et M. J. Oldham OUT-013*) and Renfrew County, Ontario, populations supported by specimens from Rolphton (*D. F. Brunton 17 078*) and Calabogie (*Bakowsky, s.n.*). *Isoetes septentrionalis* was subsequently found to be common in and about Calabogie and downstream along the Madawaska River at Stewartville. An additional, "inland" Ontario population from Lanark County is inferred from a specimen of *I.* ×*dodgei* (45.13326°N, 76.15200°W) west shore of Mississippi River 1.0 km downstream of Highway 7, Carleton Place, Beckwith

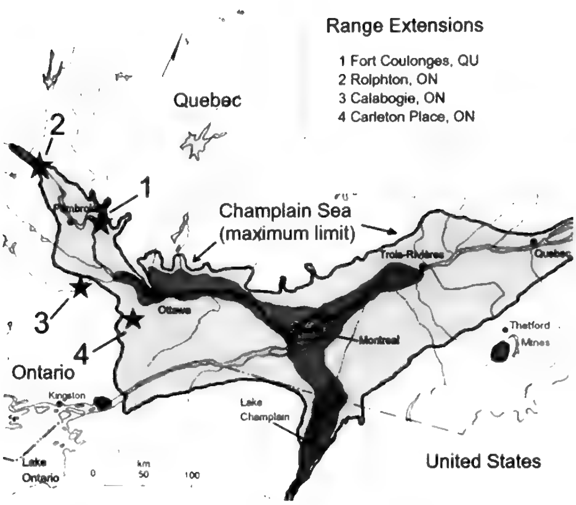

FIGURE 3. Distribution of *Isoetes septentrionalis* in Canada (excludes disjunct Hasting County, Ontario, populations 150 km to the west). Generalized extent of core range (darkest shading) is based on Cody and Britton (1989) and herbarium specimens, as cited in Methods; Champlain Sea maximum limit adapted from Occhietti (1989).

Township, 17 September 2014, *D. F. Brunton and H. Bickerton 18,871* (D. F. Brunton personal herbarium).

The core area for *Isoetes septentrionalis* in Canada is the lower Ottawa River and upper St. Lawrence River (Figure 3) where several dozen populations have been documented in a more or less continuous distribution. This core range is within or closely adjacent to the limits of the post-glacial Champlain Sea, an Atlantic Ocean embayment that was present in the lower Great Lakes region 10 000–12 000 years ago (Occhietti 1989). It is presumably not coincidental that the recent range extensions described above are within or immediately adjacent to the maximum reach of the former sea (Figure 3) .

Isoetes septentrionalis occurs in a habitat similar to the other *Isoetes* species of Ontario and Quebec; it is typically found in shallow (< 1.25 m deep), fresh water (Figure 4a) or emergent on shores in sterile sand or fine gravel, often among boulders (Figure 4b), in a sparse association with other aquatic vegetation. A distinctive characteristic of most Canadian *I. septentrionalis* populations is the presence of clay in the substrate immediately below the thin mantle of sand and gravel. Deposition of marine clay during the Champlain Sea era established an abundance of such habitat in eastern Ontario and western Quebec (Chapman and Putnam 1984).

Beneficial aspects of these otherwise uncommon substrate conditions are presumed to have contributed to the abundance of *Isoetes septentrionalis* in the core area. Hundreds if not thousands of plants occur at sites in western Ottawa (Britannia Conservation Area) and Gatineau (Deschênes) amongst the relatively numerous populations found along the lower Ottawa River.

Ontario and Quebec populations also appear to be persistent. That the large population below the Deschênes Rapids in Gatineau has been known from that location for over a century is inferred by the long-term presence of *Isoetes* ×*dodgei* (*W. H. Harrington, s.n.*, 1 August 1908 (CAN)) and the contemporary presence of both the hybrid (1 km below Deschênes Rapids, Ottawa River, Aylmer, 12 September 1988, *D. F. Brunton 8628* (OAC)) and *I. septentrionalis* (*D. F. Brunton 8629*). Indeed, the population from which the 1864 John Macoun collection cited in Engelmann (1882) was taken is still thriving after 150 years (*D. F. Brunton 15 341*).

In Canada, *Isoetes septentrionalis* is frequently found in association with *I. echinospora* and rarely also with *I. lacustris*. The presence of sterile hybrids between *I. septentrionalis* and associated species is common. Indeed, hybrids occur in most larger *I. septentrionalis* populations, sometimes in greater numbers than either parent. At the Britannia (Ottawa, Ontario) holotype location of *I. septentrionalis*, for example, a mixed population of 23,000 hybrids, 6,000 *I. septentrionalis*, and 1,000 *I. echinospora*, was estimated to be present

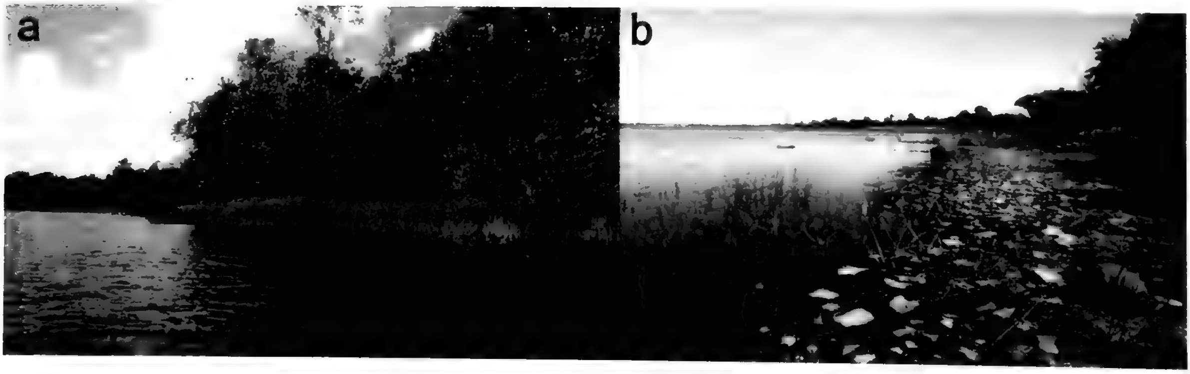

FIGURE 4. Habitat of *Isoetes septentrionalis* in Canada: (a) fully aquatic habitat (shallow, flowing water before marshy fringe), above Marmora, Ontario Iron Works ruins (site of 1864 J. Macoun collection), 24 September 2002, (b) emergent, amphibious habitat (silty sand and clay among open cobble), Britannia Conservation Area, Ottawa, Ontario (holotype location), 25 September 2011. Photos: D. F. Brunton.

on 20 July 1993 (personal observation) in an area 350 m long by 25 m wide.

The more robust stature of hybrids has often led to their detection before that of the parent species at particular sites and thus, their disproportionately higher representation in herbaria (Brunton and Britton 2006). No *Isoetes septentrionalis* hybrids are known to occur in the absence of one or (almost always) both diploid parents at any of the sites surveyed in Canada or the United States.

Not conforming closely to this distribution pattern are a cluster of sites in south-central Ontario, despite occurring in similar sites characterized by clay under sterile sand substrate in fresh, flowing water. Thriving populations exist along the banks of the Crowe and Skootamatta Rivers in Hastings County, Ontario, well west of the core area. There is no obvious phytogeographic connection between these western, apparently disjunct populations and those in the core area within the limits of the Champlain Sea. Curiously, although occurring frequently with *Isoetes septentrionalis* populations in the core range, *Isoetes* ×*dodgei* is not known from any of the Hastings County populations, despite *I. echinospora* being commonly found in the vicinity.

The thriving, distributionally atypical Hastings County populations include one of the two occurrences cited by Engelmann in his original (1882) speculation about *Isoetes riparia* "canadensis" (*John Macoun s.n.*). Although not constituting a range extension, the 2001 rediscovery of that population along the Crowe River in Marmora is useful, not only for permitting the contemporary examination of material identical to that used by Engelmann, but also as proof of the longevity of particular *I. septentrionalis* populations.

The Leeds & Grenville County, Ontario, occurrence is based on a more than century-old record (*E. P. Bicknell 11,393*). Although the site is intact (personal observation), no *Isoetes* have subsequently been found there. The existence of pre-1940 specimens from adjacent St. Lawrence County, New York (NYS), however, supports the interpretation of the Leeds & Grenville County record representing a former natural occurrence rather than a mislabeled specimen from elsewhere.

Notwithstanding densely urbanized sites which have succumbed to development and/or associated water pollution, most Canadian *Isoetes septentrionalis* populations appear to be enduring. Few historic specimen records are not confirmable by contemporary field investigations.

The distribution of *Isoetes septentrionalis* in the United States was determined from the examination of herbarium specimens during the present study (as cited above) to include at least Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, and Vermont (Figure 5). Previous *I. riparia* reports from Rhode Island and Maine are also presumed to represent *I. septentrionalis*, although specimens from those states were not examined during this study. It appears to be uncommon to rare throughout much or all of its American range (Gerke *et al.* 2014; Rhodes and Block 2000; Young 2010; Arthur Haines, personal communication).

FIGURE 5. North American distribution of *Isoetes septentrionalis* (from Angelo and Boufford 2015; Weldy *et al.* 2015; Rhodes and Klein 1993; Taylor *et al.* 1993; this study).

Conclusions

In Canada, populations of *Isoetes septentrionalis*, the northern representative of the *I. riparia* complex, are concentrated in a core area within the limits of the former post-glacial Champlain Sea. Although typically scattered and modest in size (50–100 plants), the presence of some large and long-persisting populations within the core area imply that the overall Canadian population is substantial and stable. The distribution pattern illustrated by the combination of long-documented and recently discovered occurrences, however, suggests that *I. septentrionalis* will remain rare and local beyond the limits of the former Champlain Sea.

No explanation for the occurrence of several robust and long-persisting populations well to the west of the core area is evident. The presence and abundance of a number of discrete populations in essentially pristine sites within two distinct watersheds (the Skootamatta and Crowe River systems), however, suggests that these are natural occurrences. This situation invites further phytogeographic investigation.

Acknowledgements

The cooperation of the collection managers of the cited herbaria is appreciated. Thanks are also due the late Donald Britton (1923–2012) of the University of Guelph who produced the scanning electron microscope images and granted permission for their use. He also produced the cytological data used here and shared both his insights and frustrations with this complex group. Arthur Haines, New England Wild Flower Society, Framingham, Maine, also provided helpful information on the contemporary status of *Isoetes* in New England. The review comments of Arthur Haines, W. Carl Taylor, National Museum of Natural History, Suitland, Maryland, and Paul M. Catling, Agriculture Canada, Ottawa, Ontario, are much appreciated.

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Received 11 March 2015
Accepted 26 May 2015

Notes

Record Long-distance Movement of a Deer Mouse, *Peromyscus maniculatus*, in a New England Montane Boreal Forest

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Wood, Connor M., and Shawn T. McKinney. 2015. Record long-distance movement of a Deer Mouse, *Peromyscus maniculatus*, in a New England montane boreal forest. Canadian Field-Naturalist 129(2): 181–182.

We report a single-season, non-homing movement of 4287 ± 10 m by an adult male Deer Mouse, *Peromyscus maniculatus*, in western Maine, United States, in summer 2014. The movement was achieved in two stages: 927 ± 3 m in four days and an additional 3360 ± 10 m in 44 days. This is approximately 40% greater than the previously documented maximum linear movement for an individual of this species.

Key Words: Deer Mouse; dispersal; Maine; movement; *Peromyscus maniculatus*

Although rare, long-distance movements can have major positive and negative impacts on biological communities (Trakhtenbrot *et al.* 2005). They also offer insight into fundamental ecological patterns, population genetic structuring, and metapopulation dynamics (Bowman *et al.* 2002; Trakhtenbrot *et al.* 2005). Documenting such movements, even for common species, is thus an important task. In this note, we report the longest Deer Mouse (*Peromyscus maniculatus*) movement on record.

The movement took place in summer 2014 along Bigelow Mountain, an approximately 19-km east–west ridgeline in western Maine, United States. The ridgeline is dominated by spruce–fir boreal forest (*Picea rubens* Sargent and *Abies balsamea* (L.) Miller), but individual peaks are characterized by alpine tundra. The ridgeline is traversed by the Appalachian Trail and managed as an ecological reserve; aside from two campsites, human impact is minimal. There are no major natural or anthropogenic barriers to dispersal.

Individual locations of Deer Mice were documented using a combination of live and lethal trapping during a larger study of small-mammal community ecology. High-elevation trapping efforts occurred on Avery Peak (1246 m above sea level; 45.15°N, 70.27°W) and West Peak (1265 m above sea level; 45.15°N, 70.29°W). Sherman Live Traps (Sherman Trap Co., Tallahassee, Florida, USA) were laid out in 90 m × 90 m grids (10 rows of 10 traps spaced 10 m apart), baited with oats and peanuts, and supplied with cotton balls for nesting material. Trap locations were recorded with a Global Positioning System (GPS) unit (GPSMAP 62s, Garmin, Olathe, Kansas, USA) with a location accuracy of ± 3 m. Traps were checked each morning and evening for three days, and the morning of a fourth day. All captures were identified to species, given a uniquely numbered ear tag (Monel #1, Kentucky Band and Tag Co., Newport, Kentucky, USA), weighed, sexed, measured, and marked by taking a small hair clipping before release. Distances were measured using Garmin BaseCamp (Garmin) and represent direct Euclidean movement.

An adult male Deer Mouse, tagged as 923, was captured five times on four consecutive days (9–12 June) on Avery Peak (grid 1). His maximum detected movement within grid 1 was 30 ± 3 m. Four days later (June 16) and 927 ± 3 m west, mouse 923 was captured on West Peak (grid 2). This first major movement occurred between 1000 on 12 June and 0800 on 16 June, which required a minimum movement of approximately 232 m/day. In ten weeks of trapping in 15 grids, this was the only instance where we detected an individual moving between trapping grids.

Mouse 923 was subsequently captured five times on four consecutive days (16–19 June) on grid 2. Maximum detected movement within grid 2 was 22 ± 3 m. Forty-four days after his last capture in grid 2, mouse 923 was lethally trapped on 2 August by an Appalachian Trail caretaker at Horns Pond (964 m above sea level; 45.14°N, 70.33°W), 3360 ± 10 m west of his last known location in grid 2. That suggests a mean minimum movement of 76 m/day over this last period, although the distance and duration of his first major long-distance movement indicates that he could have moved much more quickly. In 51 days after his last capture in grid 1, mouse 923 moved 4287 ± 10 m west along the Bigelow ridgeline. This movement exceeds the previous movement record for this species by 1243 m (Jung *et al.* 2005).

We are confident that the mouse tagged as 923 at grid 2 is the same as the one found in grid 1 for several reasons. First, to our knowledge, no other small mammal research has been conducted in that region of Maine in at least the last five years. Therefore, it is unlikely that an animal tagged by a different researcher could have reached our trap grid. Second, mouse 923 had a distinctive area of clipped fur along his flank, unequivocal evidence that our team had previously captured him. Third, we captured mouse 923 five times in grid 2, allowing us ample opportunity to verify that we had correctly read the tag.

During our time in grids 1 and 2, we spent several evenings conversing with the Appalachian Trail caretaker who lived on the mountain. On 4 August, he reported that, two days earlier, he had killed a number of mice near his cabin and noticed that one of them was wearing ear tag 923. He disposed of the carcass before we could verify the identity. However, given mouse 923's established propensity for rapid long distance movements (927 ± 3 m in five days between grids 1 and 2), the absence of other sources of tagged animals, the caretaker's familiarity with the project, the lack of plausible means for assisted movement, and the numerous previous instances of long-distance movements by this species (Bowman *et al.* 1999; Jung *et al.* 2005), we are confident that the mouse lethally trapped and reported as Deer Mouse 923 was indeed the same individual that we captured in grids 1 and 2.

This 4287 ± 10 m single-season, non-homing movement by an adult male Deer Mouse exceeds movements of 3044 ± 60 m and 1768 m reported by Jung *et al.* (2005) and Bowman *et al.* (1999) in similar habitat. Both Jung *et al.* (2005) and Bowman *et al.* (1999) reported long-distance movements of subadult male Deer Mice in autumn that were presumed to be dispersal from natal range. The observation of Bowman *et al.* (1999) coincided with a large-scale irruption of Deer Mice (Bowman *et al.* 2001).

We detected no evidence of irruptive dynamics (C. M. Wood and S. T. McKinney, unpublished data), suggesting that density-dependent factors did not influence the long-distance movement recorded at our study site. The mass (19.5 g) and snout to vent length (7.5 cm) of mouse 923 were in the third quartile for all Deer Mice captured that summer (N = 143, Wood and McKinney unpublished data), suggesting that size alone would not have made him a social subordinate. Fairbairn (1978) suggested that some Deer Mice display an innate propensity for dispersal regardless of social pressure and are distinguishable from their peers only by elevated levels of spontaneous activity. We have no data on mouse 923's relative level of spontaneous activity, but his overall movements revealed a pattern of two four-day periods with short, localized movements (22 - 30 ± 3 m), punctuated by major directional movement (927 ± 3 m). This pattern suggests a dynamic interplay between localized foraging behaviour and a strong innate tendency toward movement. It corroborates the increasingly well-documented vagility of small mammals (Bowman *et al.* 1999; Maier 2002; Rehmeier *et al.* 2004; Jung *et al.* 2005), which could be a key attribute for population connectivity at broader spatial scales.

Acknowledgements

We thank A. Black for assistance in the field, I. Fitzmorris for documenting the final location of mouse 923, and T. Divoll and two anonymous reviewers for their comments. We thank the Maine Department of Agriculture, Conservation, and Forestry, Bigelow Preserve, for allowing us access to conduct research and for logistical support. This research was funded by the Maine Outdoor Heritage Fund (project 141-01-04), the Maine Cooperative Fish and Wildlife Research Unit, and the University of Maine Graduate Student Government. This research was conducted under the approved University of Maine Institutional Animal Care and Use Committee protocol number A2014-04-03. Mention of trade names and commercial products does not constitute endorsement or recommendation for use by the United States government.

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Received 21 October 2014
Accepted 14 March 2015

Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in the Lower Great Lakes Region and a New Record for New York State

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Brunton, Daniel F. 2015. Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in the lower Great Lakes region and a new record for New York State. Canadian Field-Naturalist 129(2): 183–188.

Six populations of Great Plains Ladies'-tresses (*Spiranthes magnicamporum* Sheviak) have recently been discovered in three locations east of the lower Great Lakes region of Canada and the United States. The possible occurrence of *S. cernua* × *magnicamporum* hybrids was detected at one New York site. These discoveries are from both natural alvar and disturbed meadow and shore sites. The new records suggest that *S. magnicamporum* occurs more widely than was suspected previously, its presence perhaps masked by its similarity to the common *S. cernua* (L.) Richard. Eastern occurrences may represent a combination of post-glacial relict populations, responses to climate change, and the results of long-distance dispersal events. These range extensions constitute the most easterly known populations of *S. magnicamporum* in North America. They also represent new records for New York State (including Jefferson and St. Lawrence Counties) and for the City of Ottawa in Ontario.

Key Words: Great Plains Ladies'-tresses; *Spiranthes magnicamporum*; New York; Ontario; alvar; range extension; Ottawa; post-glacial relict

Introduction

As suggested by its common name, Great Plains Ladies'-tresses (*Spiranthes magnicamporum* Sheviak; Orchidaceae) is predominantly a western grasslands diploid species. The core distribution of this recently described taxon is central North America (Figure 1). Beyond there, *S. magnicamporum* is typically considered a rare disjunct, with isolated population clusters east to central Kentucky, western Virginia, southern Ohio, and southwestern Ontario (Sheviak and Brown 2002). Until recently, the most easterly occurrences were known only on the basis of 19th-century specimens from two presumed extirpated populations in southeastern Pennsylvania (Rhodes and Block 2000). It is a species of conservation concern in all or most jurisdictions beyond its core range. That is certainly true in Canada where it was known from several populations in a small area of southern Manitoba (Ames *et al.* 2005; Brouillet et al. 2010+) and from scattered populations in southwestern Ontario (Oldham and Brinker 2009).

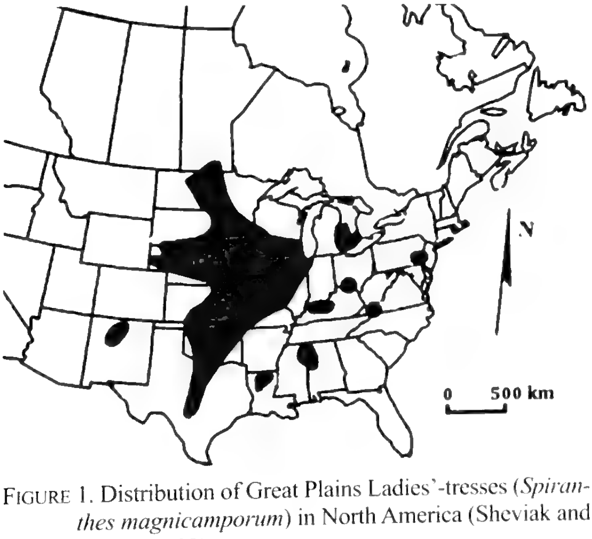

FIGURE 1. Distribution of Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in North America (Sheviak and Brown 2002).

In September 2013, a large population of *Spiranthes magnicamporum* was discovered in relict prairie habitat on the Burnt Lands alvar, Lanark County, Ontario, by P. M. Catling (Reddoch *et al.* 2013). That discovery stimulated additional field investigations and the location of new populations. This article documents those new populations and reviews the distribution and habitat of the species east of the Great Lakes.

Additional Eastern Populations

The association between *Spiranthes magnicamporum* and the provincially rare and distinctive alvar grass Northern Dropseed (*Sporobolus heterolepis* (A. Gray) A. Gray) was noted during examinations of its preferred habitat in the Burnt Lands alvar and was used as a field aid for the discovery of additional populations. In September 2014, I conducted searches for this orchid in alvar habitat supporting *S. heterolepis* populations in the City of Ottawa portion of the Burnt Lands alvar and in similar sites between Belleville and Kingston in southern Hastings and Lennox & Addington Counties along the north shore of Lake Ontario. These searches were unsuccessful, perhaps because the sites examined were drier than the *S. magnicamporum* site on the Lanark County portion of the Burnt Lands alvar.

In 2014, however, I discovered a small population of *Spiranthes magnicamporum* in moist alvar habitat 5.1 km northeast of Chaumont in Jefferson County, New York, in the Chaumont Barren Reserve (Figures 2 and 3). *Spiranthes* specialists P. M. Catling and C. J. Sheviak verified the identification from photographs of the

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A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalist's Club.

Chaumont Barren plants. This represents the first record of *S. magnicamporum* for the state of New York (Mitchell 1986; Weldy *et al.* 2015).

Twelve flowering plants of *Spiranthes magnicamporum* were initially found at the Chaumont Barren site, just coming into peak flower on 7 September 2014. The strong vanilla-like fragrance typical of this species was evident even in these mostly immature blooms. Later, 50 flowering plants were found there, including scattered individuals in a nearby *Sporobolus heterolepis* meadow, still flowering on 23 September 2014 (Holly Bickerton, personal communication).

On 13 September 2014, approximately 90 *Spiranthes magnicamporum* plants were found by Steven Daniel and Anne Johnson in a separate alvar population approximately 1 km from the first Chaumont Barren site. These plants had the leafless stems, late-flowering habit, and strong floral fragrance of *S. magnicamporum*. However, their flowers exhibited morphological features somewhat intermediate between those of *S. magnicamporum* and Nodding Ladies-tresses (*S. cernua* (L.) Richard), the common, earlier-flowering, and typically odourless tetraploid species with which diploid *S. magnicamporum* can be confused. Although no *S. cernua* plants were noted in 2014 at the Chaumont Barren, the potential for this second population to represent hybrids warrants further investigation. Triploid hybrids between these species are known but are difficult to confirm without cytological analyses (Sheviak 1991).

Spiranthes magnicamporum was found at a second northern New York location shortly after the Chaumont discoveries. On 25 September 2014, Henry Steger located 76 plants in a calcareous roadside meadow at Hopson's Bay along the St. Lawrence River at Massena, St. Lawrence County. Another Massena population (approximately 20 plants) was found shortly thereafter (2 October 2014) by Anne Johnson and Steven Daniel in a similarly low, disturbed (possible landfill) site along the north side of the Wiley Dondero Canal in Robert Moses State Park, approximately 6 km east along the St. Lawrence River from Hopson's Bay (A. Johnson in Brunton 2015). The Massena populations are approximately 135 km east of the Chaumont Barren Reserve.

In addition to the New York populations, a second eastern Ontario population was discovered in 2014. On 19 September 2014, Henry Steger found 16 plants just coming into flower in the City of Ottawa portion of the Burnt Lands alvar in Burnt Lands Provincial Park. The plants were in a formerly treed but now graminoid-dominated alvar meadow that was burned in a wildfire in June 1999 (Catling 2009). This population is located approximately 4 km southeast of the much larger Lanark County Burnt Lands alvar population found in 2013 and is the first record for the City of Ottawa (Brunton 2005).

FIGURE 2. Site and habitat of Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) at the Chaumont Barren Reserve, Jefferson County, New York (7 September 2014). Photo: D. F. Brunton.

FIGURE 3. Flowering spike of Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) at the Chaumont Barren Reserve, Jefferson County, New York (7 September 2014). Photo: D. F. Brunton.

A voucher specimen from the initial Chaumont Barren population of *Spiranthes magnicamporum* (*D. F. Brunton 18,833*) has been deposited in the New York State (NYS) herbarium. Digital photographs of the second Chaumont Barren population, both St. Lawrence County populations, and plants from the City of Ottawa site were obtained for documentation and verification purposes.

Figure 4 illustrates the known distribution of *Spiranthes magnicamporum* in Ontario and New York State. From an initial understanding of the species location close to the shores of Lakes Huron and Erie (Whiting and Catling 1986), its distribution in southwestern Ontario is now recognized to extend across virtually all of the Carolinian zone. (Note: Oldham and Brinker [2009] records shown in Figure 4 denote counties, not exact locations, where inland populations have been found since 1982.)

Spiranthes magnicamporum *Habitats and Origins*

The recently discovered populations of *Spiranthes magnicamporum* in the lower Great Lakes region occupy two quite different habitats, possibly reflecting dispersal at different time periods. Whiting and Catling (1986) describe the preferred habitat within the more or less continuous Ontario range (shaded area of Figure 4) as low prairies, littoral meadows, or even disturbed upland meadows over calcareous substrate. Similarly, Sheviak and Brown (2002) describe the plant as occurring across its North American range in "dry to wet prairies and fens," as do Rhodes and Block (2000) for Pennsylvania, Voss and Reznicek (2012) for Michigan, and Swink and Wilhelm (1994) for the Chicago region. A clear explanation for why two very different habitats appear to be used and what may have led to the occurrence of *S. magnicamporum* populations in this area will require additional research, including more field investigation in eastern Ontario, northern New York, and southwestern Quebec. There is sufficient evidence, however, to permit reasonable speculation on some likely possibilities.

The habitat of *Spiranthes magnicamporum* populations in the flooded section of the St. Lawrence River, also known as the St. Lawrence Seaway, is consistent with that of its core range, especially the more disturbed meadow habitats. It grows there in low, seasonally wet meadows in calcareous silty-sand and gravel substrate with Pringle's Aster (*Symphyotrichum pilosum* (Willdenow) G. L. Nesom ssp. *pringlei* (A. Gray) G. L. Nesom), White Flat-top Goldenrod (*Solidago ptarmicoides* (Nees) B. Boivin), and Greater Fringed Gentian (*Gentianopsis crinita* (Froelich) Ma) (H. Steger, personal communication) and at Robert Moses State Park, also with spikerushes, *Eleocharis elliptica* Kunth and the regionally rare *Eleocharis quinqueflora* (Hartman) O. Schwarz (Anne Johnson, personal communication; Eldblom and Johnson 2010)).

Contrary to that pattern, however, beyond the Carolinian zone in Ontario and the Chaumont Barren of New York, *Spiranthes magnicamporum* is found exclusively in alvar habitat. Plants at the Chaumont Barren, Burnt Lands, and Carden Plain (City of Kawartha, east of Lake Simcoe) alvars grow over limestone bedrock in the thin, seasonally moist turf of open meadows and glades in various combinations of *Sporobolus hetero-*

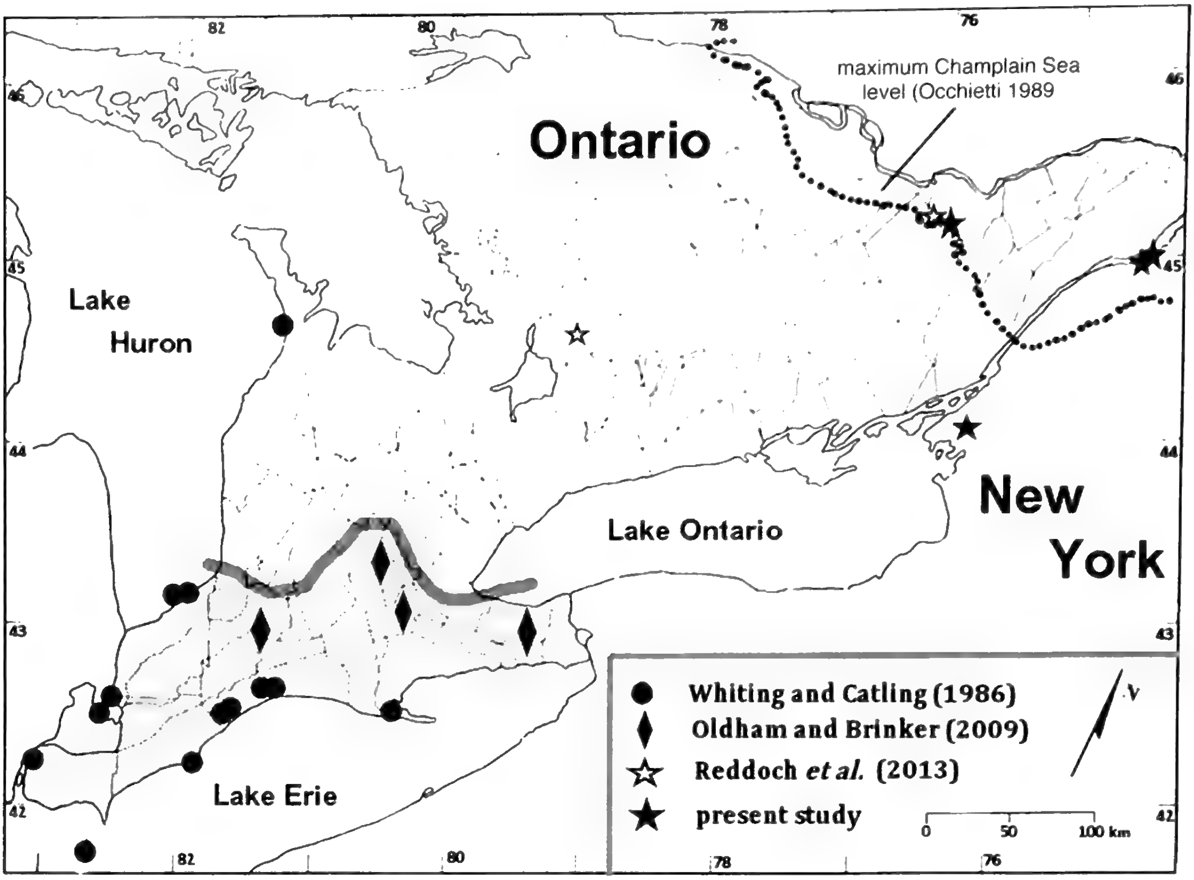

FIGURE 4. Distribution of Great Plains Ladies'-tresses (*Spiranthes magnicamporum*) in Ontario and New York (shaded area indicates continuous range within Canada).

lepis, Ensheathed Dropseed (*Sporobolus vaginiflorus* (Torrey ex A. Gray) Alph. Wood var. *vaginiflorus*), *Solidago ptarmicoides*, Prairie Smoke (*Geum triflorum* Pursh), Canada Bluets (*Houstonia longifolia* Gaertner [syn. *Houstonia canadensis* (Willdenow) Fosberg]), Wiry Panicgrass (*Panicum flexile* (Gattinger) Scribner), and/or Poverty Grass (*Danthonia spicata* (L.) P. Beauvois ex Roemer & Schultes). Elsewhere in North America, "grassy limestone barrens" in Virginia (Weakley *et al.* 2012) appear similar to that of southern Ontario alvar sites. Charles Sheviak (personal communication) notes that "the species sometimes occurs in very shallow soils over limestone in the heart of its prairie range too."

It seems significant that the *Spiranthes magnicamporum* sites on the Carden Plain and Burnt Lands alvars are geographically situated within a complex of post-glacial Great Lakes drainage features such as stranded beaches, drainage outlet channels, and fossilized dunes (Chapman and Putnam 1984). The presence of these populations and their distinctive Great Lakes and western flora and faunal associates may be related to post-glacial landscape structure and to revegetation processes thought to have provided prehistoric migration opportunities (Catling and Brownell 1995; Reschke *et al.* 1999). These *S. magnicamporum* populations, then, may represent relicts of the time when landscape forming processes were particularly active in the lower Great Lakes region (8000–12 000 years ago; Occhietti 1989). The optimum time for the migration of western and prairie species into the lower Great Lakes region including the currently known Ontario and New York range of *S. magnicamporum* would more likely have been during the hypsithermal period that prevailed approximately 8000–9000 years ago when conditions were warmer and drier than they are in contemporary times (Dadswell 1974; Mardis 2014).

Unlike those of other easternmost populations, however, *Spiranthes magnicamporum* sites along the St. Lawrence Seaway are distinctive by virtue of their prolonged, deep submergence in the post-glacial Atlantic Ocean embayment, the Champlain Sea (Figure 4). The Chaumont Barren alvar is situated beyond the reach of the sea and would have been available for revegetation shortly after deglaciation of the local landscape about 11 000 years ago (Karrow 1989). The Burnt Lands alvar (elevation 145–155 m above sea level) is situated at the western limit of the Champlain Sea (Russell and Cummings 2009). Current Burnt Lands *S. magnicamporum* sites are either at or only slightly beneath where the sea's maximum elevation (155 m above sea level) reached approximately 12 000 years ago (Occhietti 1989) and thus were available for revegetation shortly thereafter (Brunton 1986). Accordingly, potential colonization of terrestrial habitats at both the Burnt Lands and the Chaumont Barren would have been possible during the warmer, drier hypsithermal period.

In contrast, the substantially lower elevation (approximately 64 m above sea level) St. Lawrence Seaway sites would have been available for colonization for a much shorter post-glacial period, having remained submerged beneath the waters of the Champlain Sea and its subsequent freshwater phase, Lake Lampsilis (Russell and Cummings 2009). This inundation extended to approximately 8000 years ago (Mardis 2014). Accordingly, occupation of the St. Lawrence Seaway sites would have occurred under at least close to contemporary climatic and vegetation conditions as they became established subsequent to the hypsithermal period.

Another possible explanation for the occurrence of *Spiranthes magnicamporum* at the apparently regionally atypical St. Lawrence Seaway sites may be long-distance wind transport of seed, as has been shown for numerous orchid species (Arditt and Ghani 2000). Were that the case here, however, a more frequent and random distribution across this commonly available, disturbed habitat would be expected.

Range expansion due to climate change has been used to explain recent discoveries of *Spiranthes cernua* in northern Ontario beyond its previously known range (Catling and Oldham 2011). That may apply to *Spiranthes magnicamporum* as well. Were that the explanation for these eastern *S. magnicamporum* populations, however, a more random distribution and a lower proportion of occurrences in rare habitat known for supporting relict western flora would be expected.

Spiranthes magnicamporum *Status*

Eastern Ontario and northern New York populations represent the easternmost extant *Spiranthes magnicamporum* in North America. Given the success of relatively limited 2014 field investigations, the discovery of additional populations in the lower Great Lakes region seems probable, particularly along the St. Lawrence Seaway shores of northern New York, in adjacent Stormont, Dundas and Glengarry County of southeastern Ontario and perhaps in extreme southwestern Quebec. Even if additional populations are discovered, however, it is expected that *S. magnicamporum* will remain a rare and biogeographically interesting element of the regional flora.

Acknowledgements

My thanks to Paul M. Catling for sharing his Burnt Lands alvar discoveries, offering a wealth of ecological information, inspiring the initial Chaumont Barrens investigation, and providing verifications for later discoveries. Charles S. Sheviak also was quick to provide both specimen verification and valuable insights on *Spiranthes magnicamporum*. New York botanists Steven Daniel and Anne Johnson immediately employed their expert field knowledge and shared the success of those efforts. Similarly, Ontario field botanists Henry Steger, Wasyl Bakowski, and Holly Bickerton shared their *S. magnicamporum* discoveries and experience from New York and Ontario. The manuscript benefitted significantly from input and comments by Paul Catling, Holly Bickerton, Charles Sheviak, and Joyce Reddoch.

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Received 23 December 2014
Accepted 3 February 2015

Anti-predator Defenses of Brown Bullheads (*Ameiurus nebulosus*) and Interactions with Snapping Turtles (*Chelydra serpentina*)

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Moldowan, Patrick D., Matthew G. Keevil, Steven Kell, Ronald J. Brooks, and Jacqueline D. Litzgus. 2015. Anti-predator defenses of Brown Bullheads (*Ameiurus nebulosus*) and interactions with Snapping Turtles (*Chelydra serpentina*). Canadian Field-Naturalist 129(2): 189–193.

Ictalurid catfishes have sharp spines on their dorsal and pectoral fins that can be hazardous to predators. The pectoral spines may lock in an abducted position, effectively increasing body size and preventing ingestion by gape-limited predators. Further, sharp spines may injure predators or increase prey handling time, affording catfish opportunities for escape. As part of a long-term mark–recapture study of turtle ecology in Algonquin Provincial Park, Ontario, Canada, we documented the presence of Brown Bullheads, *Ameiurus nebulosus*, in the diet of Snapping Turtles, *Chelydra serpentina*. Here, we report on injuries inflicted by the pectoral spines of bullheads on Snapping Turtles during predator–prey interactions and provide a brief literature review of the functional significance and potential dangers of catfish pectoral spines to predators.

Key Words: Brown Bullhead; *Ameiurus nebulosus*; Snapping Turtle; *Chelydra serpentina*; pectoral spine; prey defense; prey handling; diet; Algonquin Provincial Park

Introduction

North American catfishes (Ictaluridae) are equipped with short, stout, flattened pectoral fin rays (Reed 1924; Fine *et al.* 1997; Fine and Ladich 2003). Ictalurid genera (bullheads, *Ameiurus*; channel and blue catfishes, *Ictalurus*; flathead catfish, *Pylodictis*; madtoms, *Noturus*) have pectoral spines adorned with sharp serrations akin to saw-like teeth and a sharp distal tip, creating a formidable defensive spine (Reed 1924; Alexander 1965; Bosher *et al.* 2006; Holm *et al.* 2009; Fine *et al.* 2011). Specialized modification of the bone and muscle tissue allows these spines to be locked in an erect position at a right angle to the fish's body (Alexander 1965; Fine *et al.* 1997; Miano *et al.* 2013). Flaring and locking of the pectoral spines increases the effective size of the catfish and, thus, deters gape-limited predators (Forbes 1989; Fine *et al.* 2011; Sismour *et al.* 2013). Predators may be discouraged from consuming these catfish as a result of injury inflicted by the spines or reduced profitability due to lengthy handling time (Moser 1986; Werner *et al.* 2001; Bosher *et al.* 2006; Nellis 2010; Sismour *et al.* 2013).

The Snapping Turtle (*Chelydra serpentina*) is omnivorous, consuming a variety of aquatic vegetation and prey ranging from aquatic insects and molluscs to fish, anurans, and, occasionally, waterfowl (Alexander 1943; Carr 1952; Hammer 1969; Punzo 1975; Ernst and Lovich 2009). The Brown Bullhead (*Ameiurus nebulosus*) has been recorded in the diet of the Snapping Turtle (Alexander 1943; Ernst and Lovich 2009). The Snapping Turtle and the Brown Bullhead have a largely sympatric geographic range in eastern and midwestern North America, both species occupying similar habitat (Scott and Crossman 1973; Ernst and Lovich 2009). As both may occur in high densities (Iverson 1982; Congdon *et al.* 1986; Galbraith *et al.* 1988; Coad *et al.* 1995; Iverson *et al.* 2000; Kaemingk *et al.* 2012), it is likely that the two species interact regularly.

A long-term study of the life history and ecology of Snapping Turtles based at the Wildlife Research Station (WRS), Algonquin Provincial Park, Ontario, began in 1972. Data are collected annually through standard field methods, including mark–recapture, nest site surveys, and radio telemetry. Turtles are captured from a canoe using a landing net or by hand, or by baited hoop trap, and transported to a laboratory at the WRS where they are measured and weighed. Turtles are marked with notches in the marginal scutes (Cagle 1939), and an aluminum tag bearing an alphanumeric identification code is affixed to the posterior marginal scutes of adults (Loncke and Obbard 1977). The Brown Bullhead is the only catfish species present at the site.

Observations

On 2 July 2010, an adult female Snapping Turtle (ID 076) was captured in Lake Sasajewun (45°35'38"N, 78°31'26"W) with a Brown Bullhead pectoral spine embedded in the tissue of her anterior left forelimb (Figure 1). The spine was removed and no complications were observed on later recaptures in 2010 and 2011–2014.

On 2 July 2014, an adult female Snapping Turtle (ID 587) was captured in Peewee Lake (45°34'18"N, 78°31'29"W). It was immediately noted that her throat was distended and, when she gaped defensively, a large black object was observed obstructing her esophagus (Figure 2A). The turtle was transported to the WRS where she was restrained, and the esophageal obstruc-

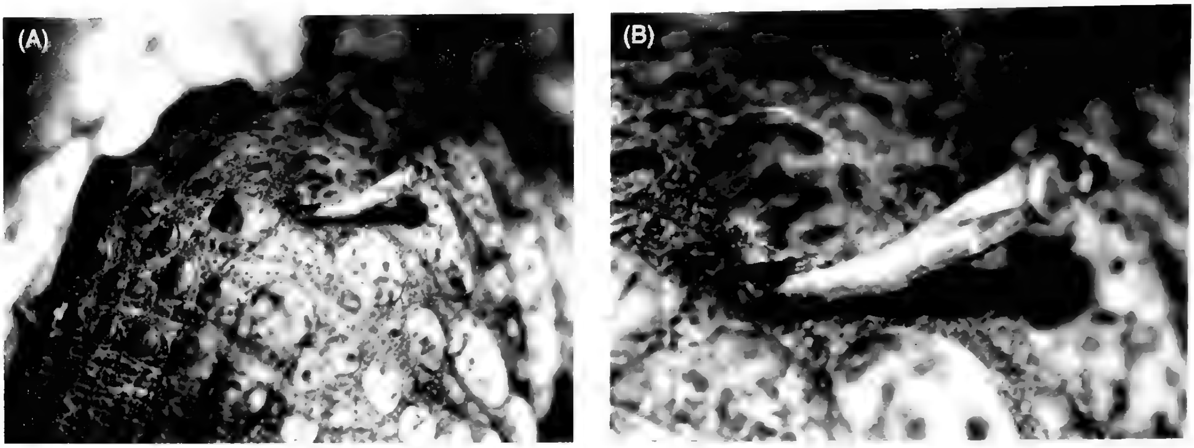

FIGURE 1. A. Pectoral spine of a Brown Bullhead (*Ameiurus nebulosus*) embedded in the anterior surface of the left forelimb of a female Snapping Turtle (*Chelydra serpentina*), ID 076, captured in Lake Sasajewun, Ontario. B. Enlarged view. Photos: P. Moldowan.

tion, a Brown Bullhead that had been swallowed tail-first, was extracted with forceps. The fish's abducted pectoral spines had punctured the turtle's esophageal tissue and caused secondary inflammation and irritation (Figure 2B). Fresh blood was visible on the throat in and around the puncture sites (Figure 2C). This turtle had been previously captured on 6 June 2014 and was observed nesting on 18 June 2014. The lodged Brown Bullhead was not observed on these dates and, therefore, must have been ingested in the 14-day period between 18 June and 2 July 2014. Also, the bullhead was in a mid-stage of decay, suggesting that it had been lodged in the throat for several days.

On 14 August 2014, an adult female Snapping Turtle (ID 721) was captured in Mew Lake (45°34'35"N, 78°31'06"W). A Brown Bullhead pectoral spine was observed projecting through the gular portion of her throat, immediately posterior to the chin barbels and mandibular symphysis (Figure 3). The spine punctured the throat from the inside. The tissue surrounding the embedded spine was well healed, but demonstrated localized swelling and irritation. The portion of pectoral spine extending outside the turtle's body was clipped with pliers, but the base of the spine inside the turtle's mouth was not removed. This turtle was not recaptured again in 2014; thus, we were unable to re-evaluate her condition. The pectoral spine injury was not present when the same turtle was previously captured on 25 June 2013.

Fin spine injuries from Brown Bullhead are seemingly rare in our Algonquin Park Snapping Turtle population. Of the 725 turtles captured in 2009–2014, the three records presented here represent a 0.4% frequency of occurrence of pectoral spine injuries. From over 2500 captures from 1972 to 2008, no catfish-spine injuries were recorded. This lack of records may reflect a lower number of injuries or a similar number of injuries that were not recognized or recorded. Two of us (PDM and MGK) were closely involved in data collection from 2009 to 2014, and observer effort in characterizing injuries was close to uniform over this period. It is notable that all three instances of injuries from Brown Bullhead pectoral spines involved adult female Snapping Turtles, although there is an overall bias toward female captures resulting from nesting site surveys; the average male:female capture ratio from 1972 to 2014 was 0.26:1. In all cases, it is not known whether the fish were taken alive or scavenged.

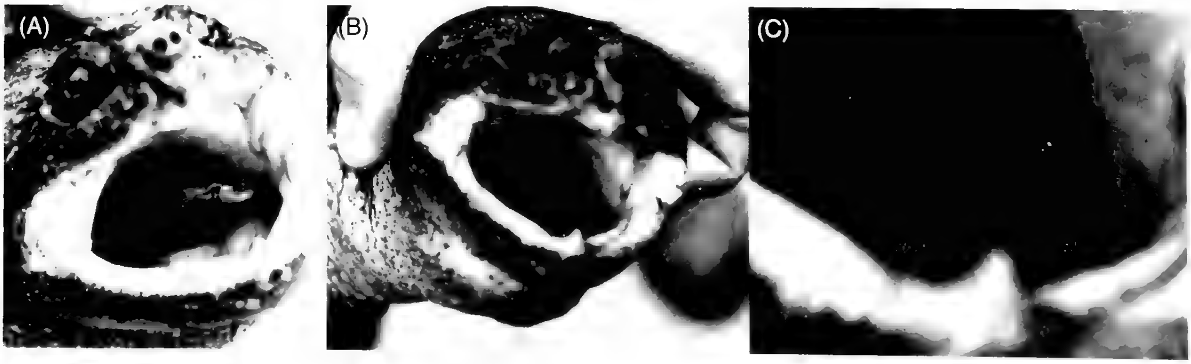

FIGURE 2. A. Brown Bullhead (*Ameiurus nebulosus*) lodged in the esophagus of a female Snapping Turtle (*Chelydra serpentina*), ID 587, captured in Peewee Lake, Ontario. B. Paired puncture wounds revealed after removal of the catfish. C. Enlarged view (only one puncture visible) showing localized inflammation and fresh blood. Photos: P. Moldowan.

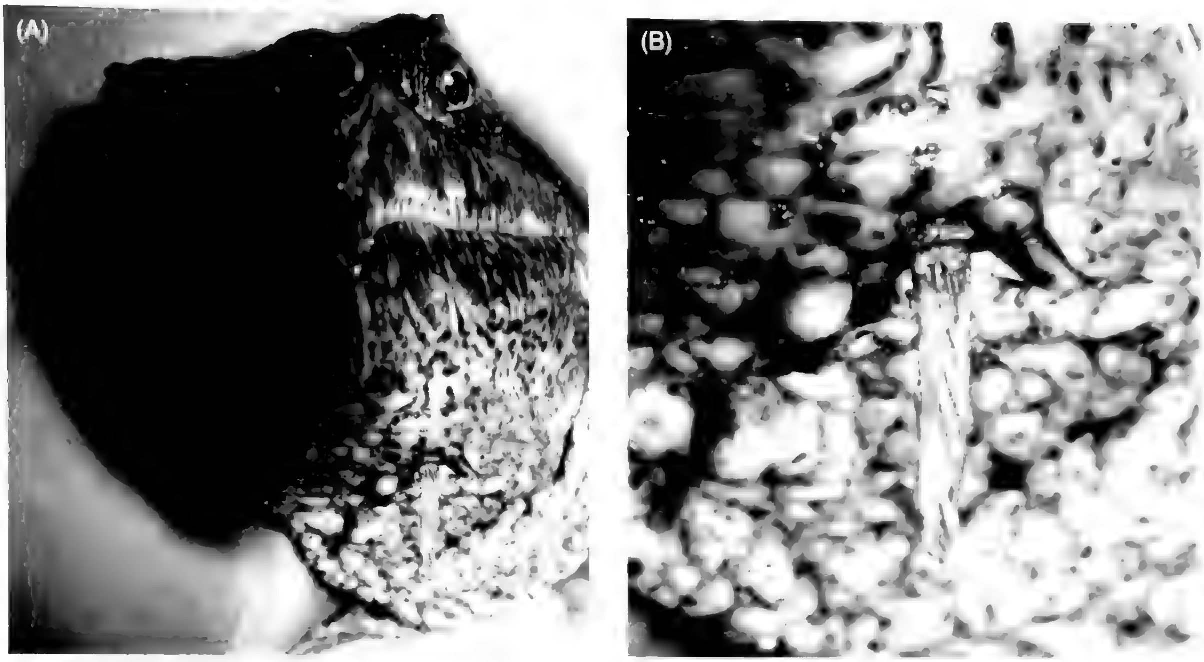

Figure 3. A. Pectoral spine of a Brown Bullhead (*Ameiurus nebulosus*) projecting through the throat immediately posterior to the chin barbels of a female Snapping Turtle (*Chelydra serpentina*), ID 721, captured in Mew Lake, Ontario. B. Enlarged view. Photos: M. Keevil.

Discussion

Our observations of injuries incurred during consumption of Brown Bullheads by Snapping Turtles provide information related to the anti-predator, functional significance of ictalurid catfish pectoral spines and the feeding behaviour and ecology of Snapping Turtles. Injuries and fatalities from catfish spines have been recorded in a number of predator taxa: fish (Scott and Crossman 1973; McAda 1983; Pimental *et al.* 1985; Ryden and Smith 2002; Bosher *et al.* 2006; Fine *et al.* 2011; Sismour *et al.* 2013), birds (Bunkley-Williams *et al.* 1994), snakes (Smith 1956; Kofron 1978; Burr and Stoeckel 2000; Gibbons and Andrews 2004; Gibbons and Dorcas 2004; Šukalo *et al.* 2012, 2014), and humans (Murphey *et al.* 1992; Baker 1997; Blomkalns and Otten 1999). The introduction of the Brown Bullhead to Bosnia and Herzegovina has proved dangerous for grass snakes, *Natrix* spp.; preying on this alien fish species has resulted in snakes becoming impaled by the pectoral spines during ingestion (Šukalo *et al.* 2012, 2014). Spines of a marine catfish species have been found embedded in the neck, flippers, and carapace of the Leatherback Sea Turtle, *Dermochelys coriacea* (Pete and Winn 1998). Recently, the spine of an unidentified catfish species was recovered from the roof of the mouth of a Snapping Turtle in Nebraska (Schmidt 2014). The spine was deeply embedded in the tissue of the palate and appeared to have been there for an extended period (C. J. Schmidt, personal communication, 2014). The lodging of an intact catfish in the throat of predatory fish (McAda 1983; Ryden and Smith 2002), birds (Bunkley-Williams *et al.* 1994), and snakes (Šukalo *et al.* 2012, 2014) is similar to that described here for the Snapping Turtle.

Considering the breadth of research on the Snapping Turtle (Lovich and Ennen 2013) and the near absence of other reported pectoral spine injuries, such injuries are probably rare. The Snapping Turtle may be particularly adept at handling catfish prey and avoiding injury from the sharp spines. Alternatively, the inconspicuous injuries caused by pectoral spines may be easily overlooked or misclassified. Soft tissue wounding is common in Algonquin Park Snapping Turtles, especially among combative males (Keevil *et al.*, unpublished data). In the absence of an identifiable spine, the cause of soft tissue injuries is often difficult to classify.

The pectoral spine of catfishes has long been described as an anti-predator adaptation (Sörensen 1895; Reed 1924; Alexander 1965), although experimental evidence in support of this idea is relatively recent (Fine *et al.* 1997; Bosher *et al.* 2006; Sismour *et al.* 2013). Rather than using the spines preemptively to ward off would-be predators, Channel Catfish, *Ictalurus punctatus*, erect their pectoral spines to discourage ingestion only when restrained by a predator (Bosher *et al.* 2006; Sismour *et al.* 2013). Abduction of the pectoral spines can more than double the width of Channel Catfish, inhibiting prey handling and ingestion by gape-limited predators, such as the Largemouth Bass, *Micropterus salmoides* (Sismour *et al.* 2013). Pectoral spines do not deter Largemouth Bass from capturing Channel Catfish, but the spines do, ultimately, decrease risk of mortality and discourage repeated predation attempts (Bosher *et al.* 2006; Sismour *et al.* 2013). Compared with fish predators, adult Snapping Turtles are only marginally gape-limited. Small prey are captured through a high-speed ram feeding mechanism (Lauder and Prendergast 1992) and may be swallowed intact (Punzo 1975; Ernst and Lovich 2009; P. Moldowan, personal observation); however, oversized prey items are held securely in the jaws and shredded with the foreclaws (Punzo 1975; Igl and Peterson 2010; Bobbie *et al.* 2015; P. Moldowan, personal observation). This tearing and dismemberment may help Snapping Turtles avoid the potentially injurious consumption of pectoral spines. It is probably this prey-handling behaviour that is responsible for the embedded pectoral spine in the forearm of Snapping Turtle ID 076.

Catfish pectoral spines can hinder ingestion, especially when the fish is swallowed tail-first, as illustrated by Snapping Turtle ID 587. Similarly, Largemouth Bass that ingested Channel Catfish tail-first experienced prey-handling difficulties (Bosher *et al.* 2006). The low incidence of pectoral spine injury in Algonquin Park Snapping Turtles may indicate that Brown Bullheads constitute a small portion of the diet, consistent with findings by Alexander (1943). Based on our direct and indirect predation observations, it seems that Snapping Turtles do not necessarily discriminate against Brown Bullheads as prey items despite the risk posed by the defensive pectoral spines (i.e., the spines do not serve as a preemptive warning). Also, given the rapid predatory strike (Lauder and Prendergast 1992) and substantial bite force (Herrel *et al.* 2002) of Snapping Turtles, the pectoral spines probably do not adequately protect Brown Bullheads (i.e., a landed strike would likely be fatal to the catfish, thereby negating the anti-predator significance of pectoral spines). As noted by Sismour *et al.* (2013), the effectiveness of catfish pectoral spines as anti-predator defense depends on relative predator–prey size and predator aggressiveness.

Acknowledgements

We thank past graduate students, field assistants, and volunteers for their countless contributions to the long-term study. We thank the Algonquin Wildlife Research Station, J. Hoare, B. Steinberg, S. Dobbyn, and Ontario Parks for logistic, in-kind, and financial support. Thanks to D. LeGros for comments that improved this manuscript. Research was conducted under approved Laurentian University Animal Care Protocols (AUP 2008-12-02 and 2013-03-01) and Ontario Parks field research permits.

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Received 9 January 2015
Accepted 11 April 2015

New Avian Breeding Records for Igloolik Island, Nunavut

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Lecomte, Nicolas, and Marie-Andrée Giroux. 2015. New avian breeding records for Igloolik Island, Nunavut. Canadian Field-Naturalist 129(2): 194–196.

New breeding records for three tundra nesting species were documented on the Arctic island of Igloolik (Nunavut, Canada). The species are the Cackling Goose (*Branta hutchinsii*), the Tundra Swan (*Cygnus columbianus*), and the Pectoral Sandpiper (*Calidris melanotos*). These records refine their breeding range in the Canadian Arctic archipelago, while highlighting changes in detected bird communities at specific locations through time.

Key Words: Cackling Goose; *Branta hutchinsii*; Tundra Swan; *Cygnus columbianus*; Pectoral Sandpiper; *Calidris melanotos*; breeding; high Arctic; Igloolik

Introduction

We conducted fieldwork on Igloolik Island (Nunavut, Canada), about 25 km from the hamlet of Igloolik from early June to early August in 2012, 2013, and 2014. This island is located in northwest Foxe Basin next to the Melville Peninsula and south of the northern part of Baffin Island. Our main objective was to study the functioning and dynamics of an Arctic food web and measure shorebird sensitivity to perturbations.

We follow the recent example of Hussell *et al.* (2012), who highlighted the importance of reporting new breeding records in Nunavut to refine our knowledge of wildlife distribution in the Canadian Arctic and report changes in detected bird communities at specific locations over time. While mapping all birds nests in our intensive study area of 0.4 km^2 and surveying a larger area of 11.7 km^2, we documented new breeding records for the Cackling Goose (*Branta hutchinsii*), Tundra Swan (*Cygnus columbianus*), and Pectoral Sandpiper (*Calidris melanotos*).

Results

Cackling Goose

Although many Cackling Geese were seen during migration, only two nests were found in our survey area, on 24 June 2014. One nest and its female are pictured in Figure 1A. The two nests were located on tiny islands in ponds located within wetland patches. Both nests were successful, with four goslings each departing from their nest on 17 and 18 July.

Tundra Swan

Two flying pairs were seen in the spring of 2012 and 2013. On 15 June 2014, a territory was detected, with a male and female showing territorial displays. At about 100 m from the territorial pair, an active nest (Figure 1B) was found on 28 June 2014 together with three older nests. The active nest contained four eggs when discovered, but was predated two weeks later.

Pectoral Sandpiper

Three nesting territories were located in the survey area in June 2012 and June 2013, especially by monitoring the distinctive hooting calls of the males (Farmer *et al.* 2013) during all days of June. Unfortunately, the nests are somewhat difficult to find as females hide beside nearby rocks without making any alert calls or displays. Among the three territories located in 2013, one nest with four eggs was found in the intensive study area on 31 June 2014. The male associated with the active nest is pictured in Figure 1C. This nest was depredated a week and a half later. On 21 July, three families of Pectoral Sandpipers were observed in the intensive study area.

Discussion

Species breeding ranges are dynamic, especially with the ongoing global changes in climate and land use (Parmesan 2006). Although breeding ranges are often portrayed as continuous spatial units, except in the case of recognized disjunct ranges, in reality they are an interpolation of discontinuous observed breeding locations (Fortin *et al.* 2005). Hence, reporting new breeding locations through various means is important to ensure ongoing refinement and adjustment of ranges, both within and outside known boundaries.

The most recent detailed list of species nesting on Igloolik Island was recorded in 1985–1986, as a result of intensive observation efforts by Forbes *et al.* (1992), who documented three new breeding species. Together with our study, the list of breeding birds of Igloolik Island now stands at 33 species recorded since the first expedition of Captain Parry in the H.M.S. Hecla in 1821 (Lyon 1824).

The Cackling Goose is a recently recognized species, formerly known as *Branta canadensis hutchinsii*, a small subspecies of Canada Goose (*Branta canadensis*). According to the range shown in Mowbray *et al.* (2002), these tundra-nesting birds are typically found on the Melville Peninsula. Despite intensive harvesting and egg collection activities on Igloolik Island during spring, we found no previous breeding records for Cackling Goose or Canada Goose on the island in eBird (www.ebird.org). Birds seen on Igloolik Island fit the general description of this species: high-pitched calls, overall small size,

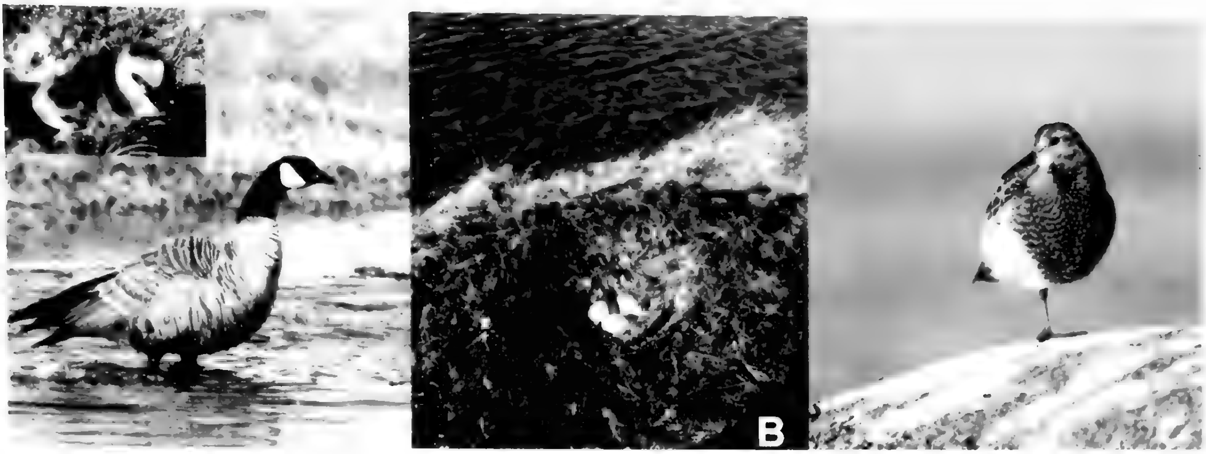

FIGURE 1. New breeding birds in Igloolik, Nunavut, Canada. A. Female Cackling Goose (*Branta hutchinsii*) with its nest as an insert, 24 June 2014 and 18 July 2014. B. The only Tundra Swan (*Cygnus columbianus*) nest discovered on the island, 28 June 2014. C. Male Pectoral Sandpiper (*Calidris melanotos*) in our study area just after a display flight and a territorial call, 5 July 2013. Photos: N. Lecomte.

light-coloured plumage, pale breast, and short bill (about a third of the head length). Cackling Geese were numerous in the area of Igloolik Island during spring migration and are known to nest further north (eBird*). There is even a nearby island called "plentiful Canada Geese" in Inuktitut (Nirlimaqtuuq). Forbes *et al.* (1992) reported that Canada Geese were uncommon, with only 13 birds observed in their two-year study compared with the hundreds we saw flying during migration every year (N. Lecomte and M.-A. Giroux, personal observations). Such an increase may reflect the steady population growth of this species since the 1970s, with the population doubling in only 20 years (Mowbray *et al.* 2002). Igloolik Island is located on the northern margin of the Tundra Swan's distribution (BirdLife International 2012*). Given ongoing global warming, which is especially rapid in the Arctic (Stocker *et al.* 2013), such a range extension is not surprising (Chen *et al.* 2011). No breeding record of Pectoral Sandpipers on Igloolik or nearby islands has been documented in eBird. However, in the last two years, evidence of breeding by Pectoral Sandpipers has been documented further north on Baffin, Bylot, and Devon Islands (eBird*). The apparently disjunct distribution in the Arctic Archipelago may be due to a lack of observations in this area.

The paucity of observers in the North compared with southern latitudes hampers our ability to track new species in the North. We recommend reporting observations of breeding locations by completing government checklists such as the Canadian Wildlife Service Northwest Territories/Nunavut checklist survey (https://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=60E48D07-1), entering data into online databases such as eBird, to which the Canadian Wildlife Service contributes by entering the checklist surveys (Canadian Wildlife Service 2007*), or through formal scientific publication. This will help identify new species breeding in the tundra and refine breeding ranges, e.g., Hussell *et al.* (2012). The necessity of consulting local communities to gather new observations, therefore, seems paramount to detecting new species arriving in this large Arctic area.

Acknowledgements

We acknowledge the community of Igloolik, the Hunters and Trappers Organization of Igloolik, and our field assistants who did outstanding work. Our research is supported by the Canada Research Chair Program, Natural Sciences and Engineering Research Council of Canada (NSERC), the Polar Continental Shelf Program (Natural Resources Canada), the Canadian Foundation for Innovation, the Environorth NSERC Create program, the Canadian Polar Commission, the Arctic Shorebird Demographics Network, Université de Moncton, and the Government of Nunavut, Department of Environment. We are grateful for insightful comments provided by A. J. Gaston and P. A. Smith on an earlier version of the manuscript.

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Received 17 September 2014
Accepted 24 March 2015

Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

ZOOLOGY

The R.O.M. Field Guide to Butterflies of Ontario

By Peter W. Hall, Colin Jones, Antonia Guidotti, and Brad Hubley. 2014. Royal Ontario Museum, 100 Queen's Park, Toronto, ON, Canada, M5S 2C6. 488 pages, 29.99 CAD, Paper.

When visiting the City of Toronto, one of the top tourist attractions is the Royal Ontario Museum (ROM). Not only is this a place full of history, it is also the home to its own publishing company. ROM books vary in topics ranging from history of cultures and Canadian heritage, to natural history, including field guides. The ROM Field Guide to Butterflies of Ontario is the first butterfly guide that has been published by the ROM. This book was written by a group of highly skilled insect experts with careers including the Senior Advisor of Biodiversity to the Canadian Collection of Insects, Arachnids, and Nematodes, the ROM entomology collections manager, the ROM entomology technician, and a zoologist at Ontario's Natural Heritage Information Centre focussing on insects.

I have always been a fan of butterflies and have recently become more active in attempting butterfly identification while in the field. I have been searching for a good field guide for a number of years now, although I could never seem to find one that really met all of my needs. Many field guides for butterflies that I have come across have either been for all of North America or Eastern North America. Although they were all good guides by well-known publishers, I have been searching for something less general and solely based on Ontario butterflies. I have come across some locally produced butterfly guides/checklists, such as the "Butterflies of Toronto" field guide. However, this was a much too localized list. After receiving this field guide to review, I felt as if all my needs in a field guide were met.

I have never been one to read the preface of a field guide, except perhaps if I needed help using it. However, this guide had an interesting preface beyond explaining how to use different aspects of the book. Within the introduction there is a brief history on butterfly research in Ontario, butterfly life history and morphology, factors influencing butterfly distribution in Ontario, butterfly conservation and protection in Ontario, and a list of 14 sites throughout Ontario to observe butterflies. These sites were chosen based on the authors' favourites, incorporating diversity in vegetation and likelihood of high butterfly diversity. Reading this information was not only interesting but also made me very excited to learn more and see more butterflies.

This ROM field guide includes all species that have been recorded in Ontario, documented in more than 800 photographs. Butterflies are categorized based on taxonomic family; each family then has a short introduction including descriptions and photos of eggs, caterpillars, and chrysalides.

Each individual species account includes photos showing the butterflies from above and below the wings, with white arrows to point out identifying features, as well a photo of their corresponding caterpillar. Figures include a distribution map of both historical and present occurrences, as well as a phenogram (spanning from March to November) depicting the flight period within Ontario's major forest regions: the Carolinian zone, mixed forest and boreal/tundra. The profile text explains observable traits of the adult butterfly and caterpillar, similar species, behaviour, overwintering stage, habitat, distribution and abundance.

When trying to identify a wide variety of flora or fauna, one of the most useful features is a distribution map to ensure that it "should" be located in the area that I am observing it in. Thus, the addition of these maps and flight season timelines is extremely helpful. Photos for all butterflies and caterpillars were of good quality and arrows pointing to main identifying features are handy for those who may not be familiar with butterfly anatomical terms.

The guide concludes with two more informative sections. First, a small compilation of other butterflies that could occur in Ontario but have yet to be officially recorded; this is complete with a photo and brief description. Second, a partial list of plants that are beneficial to plant in butterfly gardens is included. This latter section includes six pages of information about plant species and the life stage of the butterfly that uses the plant.

Overall, I would recommend the ROM's *Field Guide to Butterflies of Ontario* to anyone who is looking for a detailed and easy-to-use butterfly field guide. The introduction and final section of this guide were wonderful additions as learning tools for butterfly natural history and conservation. The conservation segment of this book also suggested that users sign up to e-butterfly (http://www.e-butterfly.org/) and assist with the sightings and tracking of butterflies, a website with a very similar appeal to e-bird (http://ebird.org/content/ebird/). The detailed butterfly profiles make identification easier through the use of photos, key features, and distribution maps. Finally, I really enjoyed reading the list of plants for use in butterfly gardens, as this list was so diverse that it made creating a butterfly friendly garden seem easily attainable. This guide has many diverse features and I feel it not only serves as a great addition to one's field guide collection, but also has use beyond that, reaching out to both the butterfly enthusiast and gardener.

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Running Silver – Restoring Atlantic Rivers and Their Great Fish Migrations

By John Waldman. 2013. Lyons Press, 246 Goose Lane, Guilford, CT, USA, 06437. 304 pages, 29.95 USD, Cloth.

Although it has been on store shelves for a little more than a year, John Waldman's book has lost none of its relevance. *Running Silver* chronicles the historic and ongoing degradation of our embattled Atlantic rivers and the decline of their migratory fish populations. These fish migrations refer to both the anadromous fish that begin their life in freshwater and then migrate to the sea, and catadromous species that spawn in the ocean and whose juveniles move into freshwater where they mature into adults. Much of *Running Silver* focuses on anadromous fish native to the east coast of North America, with occasional reference to their European or Pacific coast counterparts. Atlantic Salmon, Atlantic Sturgeon, American Shad, Rainbow Smelt, Alewife, Striped Bass, and Sea Lamprey are the main species discussed. The author also touches on some lesser-known anadromous fish, such as Shortnose Sturgeon and sea-run Brook Trout that make much shorter migrations in the lower reaches of river estuaries.

The American Eel is the only catadromous fish in North America and, as discussed by Waldman, the species' current status is as sobering as its life history is astonishing. Adult eels spawn in the Sargasso Sea near the Bermuda Triangle, and the larvae catch a ride up the eastern seaboard on the Gulf Stream. They transform into glass eels as they approach the shore and then into elvers as they move into freshwater and up East Coast tributaries. After spending 10-20 years in freshwater, they descend East Coast rivers as they make the epic return to their marine spawning grounds. Once estimated to comprise ¼ of all the fish biomass in East Coast tributaries, American Eel populations have plummeted to less than 10% of their historical abundance. Although eels have been reported to squirm up 60' waterfalls, hydroelectric dams lacking fish ladders prove an insurmountable barrier to upstream passage; on systems where eels do make it upriver, adults often run a gauntlet of turbine blades on their return descent. In Canada, young eels used to move up the St. Lawrence River into Lake Ontario in vast numbers, but have declined so precipitously that this species has recently been listed under Ontario's *Endangered Species Act*.

Like the American Eel, the decline in other migratory fish populations is a slow-motion tragedy that has played out since the New World was colonized by Europeans. No longer do East Coast rivers "run silver" with an almost unimaginable abundance of American Shad. These were truly great migrations, on par with the immense herds of bison or flocks of Passenger Pigeon. Waldman cites a French priest who described fish ascending the Kennebec River in 1723 as being "in such numbers that a person could fill fifty-thousand barrels in a day, if he could endure the labour." Sadly, the former ecological and cultural significance of these fish migrations is only dimly remembered, if at all, even in many riverside communities. Once a vital source of food for settlers and aboriginal communities, these fish populations now suffer from Pauly's "shifting baseline" syndrome. This form of collective societal amnesia results from successive generations' perceptions of fish abundance (and size) gradually get distorted over the long, slow play of time. Since memory is fallible, Waldman uses multiple lines of evidence to chronicle how fish size and abundance have declined over time. Simply put, Waldman reminds us what we have lost.

Running Silver is an important read because it takes a broad approach, encompassing the whole suite of diadromous fish from Florida to Newfoundland. It tackles a broad sweep of time, delving back into colonial history and even prehistory. Other recent works on single species, such as *The Founding Fish* (John McFee's excellent book on the American Shad), have a much more limited scope. Detailed and authoritative (as one would expect from a preeminent fisheries biologist), *Running Silver* is also very accessible and even poetic at times (the dedication to Thoreau should have tipped me off). Waldman even offers a description of an American Shad's migratory journey circa 1600 compared to 2013 from the perspective of an individual fish – definitely an eye-opener as to how the shad's world has changed. The book has some black and white illustrations as well as contemporary and historical photos, but a few more would have better connected us to the past. Additional maps, particularly of individual rivers, would also have been useful, especially for Canadian readers less familiar with the US waterways that feature prominently in the book.

Waldman chronicles the cumulative effects on migratory fish from over-harvest, mill dams, and tanneries of the bygone era, as well as more recent industrial pollution, hydroelectric dams, invasive species, and climate change. The success (or often the lack thereof), of hatchery stocking and fish "passage" efforts is also discussed. However, *Running Silver* is not all doom and gloom. The author shares stories of how committed individuals have improved the lot for migratory fish through stewardship actions, such as removal of old mill dams that are no longer needed but still block upstream passage to traditional spawning grounds. Waldman provides the incentive and playbook on how to start the long journey to restoring these great fish migrations. Not only that, *Running Silver* also reminds us that it is much easier to degrade natural river systems than it is to restore them. The Miramichi of New Brunswick is specifically cited as a river that is still in relatively good condition. We must be vigilant to preserve it and other rivers with great fish migrations, be they on our coasts, Great Lakes, or elsewhere.

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The Passenger Pigeon

By Errol Fuller. 2014. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 184 pages, 29.95 USD, Cloth.

As we all know by now, 2014 included the 100th anniversary of the death of the last Passenger Pigeon. This morbid centennial was celebrated in many ways: displays of stuffed specimens, TED talks on de-extinction, retrospectives in conservation bulletins and websites, peer reviewed papers in diverse journals and, not least, several books for children and adults to remind us of what we lost. I have read two of these, Joel Greenberg's excellent and detailed history (*Feathered River Across the Sky*), and Errol Fuller's much slimmer, but equally captivating, *The Passenger Pigeon*. For those who haven't the time to wade through the Greenberg tome, Fuller's book is where you should revel in a celebration of this fabulous extinct bird. This book offers a marvelous compendium of photos, drawings, engravings, paintings and woodcuts, a veritable visual cornucopia, supplemented by a clear, modest text. All in a compact format suitable for a small coffee table. I really enjoyed this book and have repeatedly leafed through it for the sheer pleasure of the diversity of the lavish visual depictions of this bird and its chroniclers. The text covers the essential points of the Passenger Pigeon's biology, abundance, decline and its causes, and the bird's impact not only on the physical landscape and its human occupants, but on the latter's imagination.

Fuller has written other books on extinct animals, especially birds, using a similar format of including a generous number of diverse and striking illustrations. He opens *The Passenger Pigeon* with a colourful montage of six other North American birds that have gone extinct greatly assisted by our own species. Indeed, Fuller's description of the end of the Great Auk is if anything, more depressing than the end of the Passenger Pigeon, and a surly reminder of what a murderous, destructive, and ultimately merciless ape we really can be.

In Chapter 2, titled "Imagine," Fuller uses paintings and engaging text to create an almost lyrical, legendary picture of the extinct bird. The text is to me the most strikingly real depiction of anything I have read on this lost species. Fuller creates a fictional farm family in the early 19th century as they experience the rolling thunder of a spring super flock that settles on the farm for a rest and to dine out. The text is accompanied by a truly spectacular painting of a huge, falling, broken tree limb covered in hundreds of pigeons whose combined weight has caused it to break, and the story and illustration conjure up an apocalyptic vision of the Passenger Pigeon's huge flocks rather than the usual romanticizing pictures of today. One can now imagine that, although the billions could elicit awe and provide lunch, they could have a disastrous impact on farm communities with total destruction of crops and orchards, and contamination of water and soil, with severe consequences for years to come.

Fuller sums up that we and the pigeons were incompatible, much like say, large flocks of Canada Geese or starlings today, but on a truly horrific scale well beyond some droppings on a golf course, or noise in a genteel suburb. This conflict led to an unplanned asymmetry of our relationship, and the razing of vast tracts of forest, the technological development of an efficient market hunting industry, and a complete lack of protection or conservation initiatives, combined with the irresponsible parental behaviour of the species, led to its accidental and inevitable decline.

The next chapter, "The Bird", recounts the widely known, though limited, physical and numerical properties of Passenger Pigeons, again accompanied by photos, paintings, and maps. A rare photo of the sloppy nest typical of pigeons and doves is rather sad with its single white egg. Like all photos of living birds, this was in an aviary and black and white. The chapter also includes a depiction of the pigeon's vocalizations in formal musical notation (from The Auk 28 (4): 1911), with the different sounds being shown with a brief description of the accompanying behaviour. Most quaint are the sounds made as the male moves "masterfully toward female." Despite this heroic effort to leave us with the sounds of pigeons cooing in our ears, I found, as in Greenberg's book, that I still had no idea of how they really sounded, except that they appear to have been much more diverse vocally than the monotonous cooing of modern Rock and Mourning Doves. Perhaps naturalists of the 1800's had better imaginations that the modern Sibley and Peterson guides. Suffice it to say, that imagination plays a big part in the sights and sounds presented in this lovely book.

A chapter on "The Downward Spiral" dutifully describes the collapse of the vast hordes. The lessons are there too. As populations decline and people begin to notice and they report their suspicions, they are accused of scare mongering, lying, and trying to take cheap food from the bellies of the poor. Alternative explanations abound, mainly that the birds have moved "somewhere." This pattern often occurs as species decline, even when there is good scientific evidence of decline as, for example, with the Atlantic Cod and Polar Bear today. Defenders of the status quo argue to allow exploitation to continue. A recent paper (Biological Conservation 180: 11-20) concludes that if the Passenger Pigeon had been assessed by modern IUCN/COSEWIC criteria it would have been listed as Threatened decades before its demise. As it was, that sort of protection only occurred after it was literally extinct in the wild.

"Extinction" continues from the theme of decline and tries to illustrate how apparently inevitable it was in the face of inexorable anthropogenic pressures. This line of thought is certainly open to debate, and I wonder how many of our current species at risk – for example, the Sage Grouse, Woodland Caribou, or many species of turtles – are in that sinking boat. I don't hear this debate going on given the optimistic self congratulatory pleas for funds from many conservation organizations and our so-called recovery plans trumpeted by governments. Sadly, the dystopian views of doomsayers seem right on target when we see, for example, how the Ontario government has gutted its much ballyhooed 'Endangered Species Act' (the "best in the world"), creating almost unlimited exceptions to allow industry to "kill, harass, disturb" species at risk. But I digress.

The chapter on the last captive individuals, including Martha, is illustrated largely by black and white photos of captive birds and shows that right to the end there was no real push to save the species. It was still inconceivable that it would disappear. This is eerily similar to our inability to believe that climate change will destroy modern civilization.

"Art and Book" is, in many ways, the star chapter of the book. From the detailed reproduction of a giant mural on the side of a downtown Cincinnati building showing the noble Martha (21 feet from head to tail), to a wealth of artwork and literature, we are treated to an incomparable picture of this haunting tale. Fuller is blunt in his comments on some of the artwork, most notably on the pedantic criticisms of Audubon's famous watercolour of a pair of Passenger Pigeons. He casually notes that art experts often sneer at "wildlife art," and I have heard these sneers since my youth. It seems to me that this elitist attitude arises at least partly from the fact that most academic art experts are uninterested in nature and see depictions of it as banal copies. That is their loss. Academic scientists on the other hand prefer 'accurate' copies, and Fuller has teased those experts with some quite unconventional renditions of the birds, my favourite still being the broken limb referred to earlier. The chapter is filled with pictures of a diversity of art, artists, and writers (Louis Agassiz Fuertes, James Fenimore Cooper, Charles Knight, Fred Bodsworth, Allen Eckert, and more) who have depicted the tragedy of species' extinction in word, paint, and song.

The book concludes with quotations and pictures of several luminaries who saw and commented on Passenger Pigeons. There is an appendix too with paleontologist Julian Pender Hume comparing the extant (barely) Pink Pigeon of Mauritius, the ubiquitous Rock Dove and the Passenger Pigeon. This comparison is more technical than the rest of the book, and illustrates in words, drawings and photos that the Passenger Pigeon was indeed a flying machine built for speed, the Avro Arrow of Columbiformes.

In summary, this is a beautiful book and bound to fascinate any person concerned about conservation, evolution, art, and/or birds.

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BOTANY

À la découverte du Nord: deux siècles et demi d'exploration de la flore nordique du Québec et du Labrador

By Jacques Cayouette. 2014. Éditions MultiMondes, 930 rue Pouliot, Québec, Québec, Canada, G1V 3N9. 363 pages, 49.95 CAD, Cloth.

It takes only a few minutes of perusing this publication to recognize its value in documenting the botanical exploration of Québec and Labrador north of 54° latitude. For one who has examined numerous herbarium specimens from the region, this publication brings new insights into the lives and work of many historical figures, as well as the many more recent contributors including those of former colleagues. The author has meticulously compiled, mainly in chronological order, a compendium of contributions for more than 420 explorers, researchers and others who have, in one form or another, enriched the botanical and natural history knowledge of the region in question. The publication is replete with about 400 illustrations, primarily in colour.

These include images of the individuals themselves, maps and routes taken, portions of field journals and publication listings, title covers of older publications, as well as photos of collection sites. The latter provide a vivid visual record of collection sites and habitats for specimens whose localities are known to most of us engaged in systematic studies only from names on herbarium specimen labels.

The book is organized into seven sections and 27 chapters. The care taken in presenting the information is evident beginning with the table of contents. This provides a very useful overview of the contents within each chapter for each of the sections by listing the primary topics covered and individuals treated. The seven sections are as follows: 1) natural sciences of Hudson Bay during the 17th to 19th centuries; 2) Moravian missionaries as pioneers of the flora of Labrador; 3) early contributions by Canadians; 4) major contributions of Americans and Europeans; 5) major Québec figures; 6) the many northern projects by governments and eastern Canadian Universities; 7) developments in the North confront the protection of the flora. An introductory text for each of these sections provides a brief overview and background for the information to be presented in the chapters to follow.

The chapters provide detailed biographical information on individuals, their projects, and collections. In addition, what makes this book unique is that it is a treasure trove of photos of explorers, botanists, and naturalists providing a visual "who's who" highlighting individuals, past and recent, who have contributed to the botanical knowledge of northern Quebec and Labrador. Individuals mentioned include: Joseph Banks, Robert Bell, John Macoun, Arthème Dutilly and Ernest Lepage, Nicholas Polunin, Jacques Rousseau, and Alf Erling Porsild. The many contributions by individuals of Québec universities, including those from Laval, McGill, Sherbrooke, and Montreal, are detailed as well as projects and individuals of government departments.

The colour landscape panoramas and habitat photos from sites where collections originated contribute much to the showy "coffee table" appearance of the book. Interspersed, also, are colour images of species in their natural setting or of herbarium specimens which were the basis for the description of a new taxon from a specific locality. An update on the current taxonomic status of these are also provided. Of much historical interest, also, are the archival black and white images of Moravian missionaries, images of early forts and settlements, and group photos of explorers and researchers in the field.

The book concludes with a summary and explanation of the main information sources used in preparing the contents, and provides a substantial bibliographic list of about 1000 references.

The book is a must-have reference work for serious students in systematics, for naturalists interested in the historical events leading to the botanical exploration of the region, and for institutions documenting Canada's flora. It provides the historical context behind the collectors, their travels, and varied research projects, and the resulting collections that document the flora and are housed in our national and regional herbaria. It also fosters a better appreciation of the degree of effort that has been expended by so many individuals over the past two and a half centuries in amassing the current knowledge on the vegetation and flora of this sizeable northern region of Canada.

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Trees of Western North America

By Richard Spellenberg, Christopher J. Earle, and Gil Nelson. 2014. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 720 pages, 29.95 USD, Paper.

I like this book. First of all, it looks really nice. The cover design is attractive with good choice and placement of images and colours. Secondly, it feels good. It has a nice weight, enough to be taken seriously but not so heavy that I would never carry it around. That is to say, it's about the same weight as the newer field guides for other taxa, so if I wanted to take a tree book into the field, I might take this one. It also looks rather handsome sitting on my desk, so I might leave it there. Also, it fits in one hand, open. I have small hands, but the spine is just the width of the basin of my cupped palm. Its pages fall open far enough to see, without cracking the binding.

I am not a tree expert, and for the rare times I need to pin down a hard-to-identify tree with absolute certainty I know to look for a technical reference. The rest of the time I am in the audience for a book like this. It contains an ample introductory section with lots of information about tree biology and features, and forests. The introductory section also includes discussion of taxonomy and nomenclature, which are important and, of course, very interesting. The language is neither too simple nor too technical, but just right for a well-read non-expert. Technical terms are included, and explained: "Leaves, twigs, fruits and other plant parts may be *hairless* (*glabrous*) or *hairy* (*pubescent*). The hairs, which in plants are called *trichomes*, take many forms ..." Italics theirs. It looks as though italicized terms appear in the glossary (yes, 'hair' is there) although I didn't see this explained in the text. I assume it's there somewhere.

This is a field guide for western North America, west of the 100th meridian. Being in the east, I had to be creative about field testing. However, I looked at two common eastern conifers as if I didn't know what they were and tried to identify them using this book. I failed, and that's good. Neither Eastern White Pine (*Pinus strobus*) nor Eastern White Cedar (*Thuja occidentalis*) are in the book and, thanks mainly to the well-illustrated whole trees, I didn't manage to make them fit another species. I also happen to know of an unlabeled Ponderosa Pine (*Pinus ponderosa*) near my home and, even without the context of being in range, the illustrations and descriptions led me easily to the correct species.

The identification information, along with text, includes paintings of whole trees, leaves, bark, flowers, seeds and fruit, and occasionally twigs and buds. Similar species to rule out are discussed. The "Quick ID" tips may be all you need to zero in. For less overtly distinctive species found in both the east and west, it is apparent that the user really would want to be in a species natural or naturalized range in order to come up with an identification, to eliminate similar species. This was the case, for example, for Balsam Fir (*Abies balsamea*), White Spruce (*Picea glauca*), and Blue (Colorado) Spruce losing its blue cast (*Picea pungens*).

I've only mentioned conifers so far. It is winter here, now, and the only key in the book relies on leaves. Once you've got your leaf in hand, the book should lead you to the correct general section and, assuming you know your geographic location, you would browse to find what you are looking for. If you're used to using leaf scars and buds to identify leafless trees you may find yourself frustrated by this book.

I also considered the book for its use as an overview to the trees of an area. I pretended I was going to move out west and wanted to know what I might expect. Asking friends to name places, I randomly chose two locations: Prince Rupert, British Columbia and Bismarck, North Dakota. By browsing, looking at range maps, and making lists, I came away happy that I had a good start on what trees and shrubs to expect. It was looking a bit bleak for Bismarck at first, as most of the species to be found there were further along in the book's taxonomic arrangement, while most of Prince Rupert's were in the earlier sections. The range maps include the species' entire range in Canada and the United States. They are not chopped off at the 100th meridian. They do end at the Mexican border, however. They also do not extend west of the Aleutian chain to Siberia, although I could only find one species that would.

The book includes both native and naturalized species (growing without help from humans). See, for example, the many *Acacia* and similar species in the southern United States. It includes species that are considered shrubs in some places, and cacti. On flipping through, the brightly coloured cactus fruits and flowers will grab your eye. Illustrations are paintings by David More. I find the style to be very good. It is that fine combination of precision and just the right touch of necessary impressionism. The colours, as printed, seem accurate.

I can recommend this book for the large and varied audience of those interested in trees. I will leave it to others to say how far it can go for the technical user.

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OTHER

Algonquin Park. A Portrait: The Landscape, Wildlife and Ecology of an Iconic Canadian Treasure

By Jan Rinik, and Martin Rinik. 2014. Formac Publishing Co. Ltd., 5502 Atlantic Street, Halifax, NS, Canada, B3H 1G4. 300 pages, 34.95 CAD, Cloth.

Having spent part of each of the past 50 years or so working and playing in Algonquin, I am naturally interested in books on my favourite place. Coffee table style books on the Park are many, but rather stereotyped, usually full of photos of sunsets and close ups of wolves, moose, bears, and loons. Despite spending 1000's of hours in the Algonquin wilds, I rarely have close encounters with these icons; rather it is mosquitoes, biting flies, green frogs, turtles, leeches, dragonflies, mosses, and trees that I encounter often. Those photos of winsome wolf faces seldom evoke any sense of nostalgia or reminiscence in me. I was therefore pleasantly surprised on opening this book to feel a yearning to get back to the Park, to again smell the piney summer air, the moldy, snapping turtle essence of fall, to see babbling spring freshets, and hear frogs and those warblers whose songs I must relearn each year. This is a beautiful book, lovingly produced and lavishly illustrated, not with repeated close up photographs of charismatic megafauna, though there are some, but with landscapes, often beautifully painted or drawn. And that is not all. There are many pencil drawings of birds, mammals, insects, fish, plants, and fungi often interspersed with crisp photographs and paintings of these "other" fauna and flora. The ultimate effect of this splendid assemblage of form, colour, and scenery was to create a visceral need to get back out there, and experience that special evocation of the senses that is the Ontario wilderness. Sadly, I first opened the book in winter, over 1000 km from the Park. Happily, with this splendid book, I could now be there. I have spent several hours scattered through the endless snowstorms of the 2014-

15 Maritimes' winter gazing at the paintings and photos of the four seasons of Algonquin.

In the Preface, the Riniks make the interesting point that many visitors to the Park see much less than they expected. Certainly, this is true for the busy summer season when zillions of vacationers race along Highway 60, only screeching to a halt when a hapless moose is spotted. In summer, the highway and campgrounds are filled with people, dogs, radios, cell phones, and the cursed WiFi. As a child, I was similarly disappointed on my first trip to Algonquin in the family sedan, as in mid-July we drove across Highway 60 from west to east and back and saw nary a single bit of identifiable wildlife, not even the wild Indians which I thought might lurk in the bushes. Disappointment is to be expected when we have been conditioned to expect wildlife frolicking at every kilometer. The Riniks say they hope to bring the reader closer to the wildlife. I think they do something far better. They give the reader a sense of the variety of experiences available and of the variety of perceptions attached to each of these experiences. A painted landscape or flower differs from a photograph or line drawing, Every page presents something different in scale, diversity, season, and illustrative style. It is delightful.

The book starts with a brief history of the Park and some facts and figures on its size, numbers of bird, mammal, etc. species. Here and throughout the text is readily grasped information for the newcomer and light refresher for the hardcore gourmet. Relaxing stuff. The rest of the book is organized into four chapters, one for each season. As in real life, I found the spring and fall most enjoyable, summer a bit heavy on green and charisma, and winter spartan and Canadian, and seriously attractive. The summer does have more coverage of individual species, though my experience is that most of them are less likely to be observed then, because of the human hurly burly. The number of pages devoted to each season is: spring 44, summer 70, fall 40, and winter 20.

This is the perfect coffee table book to me. It is beautifully laid out, the reproductions and production in general are a wealth of colour and visual detail of excellent quality. I particularly appreciated this quality as this is a Canadian publication, and very affordably priced too. Canada can still do it. I highly recommend this book to anyone who has or wishes to indulge in the beauty of Algonquin. If you are stuck in dreary suburbia, a sterile office, or a humbling hospital bed, this book will conjure up the real thing, and lift your spirits, and there will be no black flies, icy winds, long drives on the 400, or bears that will bite your feet. You can be transported to a heavenly place with a glass of wine for a companion.

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Rare – The High-Stakes Race to Satisfy Our Need for the Scarcest Metals on Earth

By Keith Veronese. 2014. Prometheus Books, 59 John Glenn Drive, Amherst, New York, USA, 4228-2197. 270 pages, 25.00 USD, Cloth.

Geology and mining do not necessarily come to mind when thinking about books for those interested in natural history. This book is sure to satisfy one's curiosity surrounding the lesser known and increasingly more desirable elements in the periodic table. The author discusses a variety of "rare" metals and elements (tantalum, lanthanum, thorium, etc.) and explains their distinctiveness and usefulness in today's changing social and technological world. Although the book description gives the impression that only the rare earth elements will be explored, more commonly known elements such as gold, platinum, and uranium are also discussed. This book is not geared towards geologists or any vocation in particular, but rather towards people who have a desire or general interest in learning more about rare minerals. This book provides an assortment of information about important rare elements including, but not limited to, their chemical properties, historical background/importance, and political/geographical/economic impacts in the present and future world.

The book did not seem to follow a specific plan or formula in regard to each different element that it discussed, although it does succeed in touching upon the most important and interesting facts for each element. If certain subject matters are not as captivating to the reader, the subject matter changes quickly and does not dwell on one topic for long. The book is well researched, with extensive references and notes. It is an easy read and even the more technical aspects are well-written and explained. The author references very current events and also well-known fictional movies, which suggests that the book is also meant to be a little light and enjoyable, and not completely business.

The middle of the book has eight pages of colour photos; however, many of the photos are not referenced in the text and do not seem to have any correlation, or act as a direct visual aid, to the text in the book. There is also a thorough index included which is obviously useful in tracking down specific information. The book is relatively short and broken down into small chapters for an easy read.

A reader from the environmental audience is sure to note that there are significant potential environmental impacts with the growing demand for these metals, especially the locations in the world these metals are situated (geography and politics). The environmental impacts surrounding the mining of these metals is not the main focus of the book; however, there is enough evidence given to appreciate and have concern over the impact on the environment in the different regions of the world.

This work is generally very informative and leaves the reader with a better understanding of the multidisciplinary significance of some of the increasingly important and lesser known elements. Anyone with any interest in geology will enjoy it and learn from it, as well as people interested in the global environmental issues of today and tomorrow.

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My Watery Self: Memoirs of a Marine Scientist

By Stephen Spotte. 2015. Three Rooms Press, New York Publishers Group West / Perseus, 1700 Fourth Street, Berkeley, CA, USA, 94710. 164 pages, 15.95 USD, Paper.

Stephen Spotte's book, *My Watery Self*, traces a fascinating and, at times, hilarious trail through a life that began in West Virginia coal camps, drifted through reckless bohemian times of counter-cultural indulgence in Beach Haven, New Jersey, among other places, and led to a career as a highly-respected marine biologist. As the book jacket indicates "Spotte's singular voice offers a wet and occasionally very weird perspective on the world. The stories he shares – such as his stint as curator of the New York Aquarium at Coney Island at the tail end of the hippie era – are compelling and thoroughly enjoyable as he elevates the people and situations he encounters to mythical levels, blending empirical observation with literary prose."

Amazon.com had a slightly longer review of Spotte's newest book, and I find it worthwhile to include the non-redundant information here: "Together, these stories form a view not just of one man's life, but that of a generation that often refused to take a direct path to the workplace, insisting instead on a winding unveiling of true self-realization, to achieve previously-unimagined outcomes. For Spotte, the key was water: His years of beach living led to a self-initiated study of literature and the sea. He eventually returned to college and received his training as a marine biologist, and discovered, through his singular voice, a wet and occasionally very weird perspective on the world."

This book might be the most random and non sequitur book I have read, as some of the stories are so outlandish that they are hard to believe, and "any chronology is unavoidably artifactual in this sense…since memories are drifted across my consciousness as fragments often displaced out of time" (p. 137). As indicated above, the book starts in West Virginia during Spotte's adolescence with characters such as Earl and Mr. Howard and his boys, and includes fist fights over possession of a fish (a Redhorse to be exact). The next chapter then includes a nameless drunk circus roustabout (i.e., an unskilled, casual laborer) with scrawny chicken hands who watched his girlfriend die after falling from the tightrope. Spotte (p. 24) includes a great passage on how strange it is that certain stories can become a part of you that you don't forget even if you weren't there to witness the event. After that, we move to Spotte's young adulthood and his experiences with lots of alcohol and drugs, and his ability to make homemade LSD – an interest in chemistry that would later help him with his chosen profession as a marine scientist. Many of the anecdotes recalled in this book from Chapter 3 on include alcohol, drugs, sex (including prostitutes), and lots of foul language.

While these stories might sound bizarre for a well known marine biologist with 18 books to his credit (three of them fiction) and over 80 scientific papers on marine biology, ocean chemistry and engineering, and aquaculture, they are all true according to him (see p. 136), which he confirmed in an email exchange with myself as I wrote this review! It might be a stretch to suggest given the long time-frame of these stories (from 50+ years ago), but a few pictures interspersed in the book would've been great, such as the 1962 picture that he recalled of him and two friends (p. 35), presumably when they weren't drunk or on drugs (ha-ha). The interesting thing about the book, however, was that each section, no matter how peculiar, tied into the author's love of water, whether it be ocean or freshwater, and that this random path led him to where he is today.

A few chapters center on his jobs at various aquariums including Aquarium of Niagara Falls, New York Aquarium, and Mystic Aquarium. For those jobs, he traveled to many places, such as the coasts of Rhode Island and New Jersey to try and capture sharks to bring back and exhibit at the aquariums. The methods, including killing sharks that they didn't want for the aquariums, would irk many conservationists today, but we are talking about the 1960s for many of these stories. At one point in his adventures, he falls overboard (p. 53-55) during a violent storm and has to use his pants as a makeshift life jacket to avoid drowning. Spotte was rescued after spending multiple hours in the water (luckily he didn't appear to be drinking at the time!). Another incident, in a coral reef off Key Largo, Florida, involved an underwater acid (LSD) trip in the middle of the night to make a major life decision regarding selecting a new job (you have to read p. 67 to find out what that was).

The latter half of the book focuses on his experiences capturing whales for the various aquariums he worked at. One instance involves three local thieves helping him tube feed a baby pygmy sperm whale at night in Brooklyn, New York. I laughed out loud envisioning Spotte (p. 79) yelling to one of them "Hey you. (*Expletive*). Hand me the bucket... What the (*expletive*) is wrong with you, you deaf?" After a very non sequitur chapter on Freddy the con man and supposed automobile magazine reviewer, we jump to tales of Spotte visiting the Arctic to capture belugas, which he calls belukhas to distinguish them from a fish with the same name inhabiting Russian waters. Spotte took three trips to the mouth of the Churchill River entering into Hudson Bay to try and bring some whales back to the aquarium he was working for at the time. Some of his travels were before and others after the passage of the *Marine Mammal Protection Act* (1972), which created much more bureaucratic paperwork. Spotte notes that these excursions for capturing whales would never occur in today's world. But the side events, with lots of drinking and interactions with the local Inuits were, as usual, very Spotte-like. His scary trip to Newfoundland (with the purpose of capturing dolphins for exhibit), in which the plane he was on "lifted off with the grace of a crippled goose" (p. 121) nearly ended his life when bad weather forced an emergency landing with first responders literally on the runway expecting the plane to crash upon impact. Spotte and the crews' survival, of course, meant celebrating which involved additional quantities of beer.

I thought the book was very funny and an overall page turner. Others might be turned off by the swearing, drugs, alcohol, discussions of sex, and the seemingly randomness of this book, but I found myself continually going to a new chapter without pause. I do wish the book had a bit more discussion on how these events helped shape who Spotte is today. It also could have fleshed out how all of these events helped him secure the jobs that he eventually received. Most chapters were about stories when he was here or there, but not really about the process of how Steve got there. I say that because I am always interested, as a biologist myself, on the paths people take and how they end up where they are. However, a nice Introduction by Dr. Robin Overstreet helps provide some perspective to Stephen Spotte both as a biologist and as a person, which gives the reader a better understanding of the author. Also, the last chapter does justify the randomness, i.e., the format, of the book where he discusses time and reality noting (p. 136) "how reliable is memory when reality itself is a construct?" In that last section, he also explains his background from West Virginia where the majority of people view nature as utilitarian and animals needed a purpose to justify their existence (p. 137-140), and how events should be interpreted in the context of history and culture (p. 140) such as his past participation in live-capturing whales and shooting seals.

However, the very end of the book is nicely summarized when Spotte tries to make some sense of his past, saying (p. 141) "To me the emergent world is a noisy, unpleasant place overflowing with deceit. I mistrusted it as a child and still do. Underwater, the silence lets me speak inside myself, and I can hear secret things." For those that want to read an eccentric, funny, and ridiculous account of a marine biologist, try *My Watery Self*! It is relatively short and easy to read but includes enough details and narrative to make it well worth the investment.

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NEW TITLES

Prepared by Roy John

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ZOOLOGY

Arthropods of Canadian Grasslands (Volume 3: Biodiversity and Systematics, Part 1). Edited by H.A. Cárcamo, and D.J. Giberson. 2014. Biological Survey of Canada c/o Entomological Society of Canada, 393 Winston Avenue, Ottawa, ON, Canada, K2A 1Y8. 413 pages, 45.95 CAD, Paper.

Arthropods of Canadian Grasslands (Volume 4: Biodiversity and Systematics, Part 2). Edited by D.J. Giberson, and H.A. Cárcamo. 2014. Biological Survey of Canada c/o Entomological Society of Canada, 393 Winston Avenue, Ottawa, ON, Canada, K2A 1Y8. 479 pages, 45.95 CAD, Paper.

A Buzz in the Meadow. By Dave Goulson. 2014. Random House Canada, 1 Toronto Street, Ste. 300, Toronto, ON, Canada, M5C 2V6. 266 pages, 18.99 CAD, Paper.

Butterflies. By Ronald Orenstein. 2015. Firefly Books Ltd., 50 Staples Avenue, Unit 1, Richmond Hill, ON, Canada, L4B 0A7. 288 pages, 39.95 CAD, Cloth.

* **The Kingdon Field Guide to African Mammals, Second Edition.** By Jonathan Kingdon. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 544 pages, 49.50 USD, Paper.

Handbook of the Mammals of the World – Volume 5, Monotremes and Marsupials. Edited by Don E. Wilson, and Russell A. Mittermeier. 2015. Lynx Edicions, Montseny, 8, E-08193 Bellaterra, Barcelona, Spain. 799 pages, 160.00 EUR, Cloth.

Firefly Encyclopedia of Reptiles and Amphibians. Edited by Chris Mattinson. 2015. Firefly Books Ltd., 50 Staples Avenue, Unit 1, Richmond Hill, ON, Canada, L4B 0A7. 272 pages, 49.95 CAD, Cloth.

* **Wolves on the Hunt – The Behavior of Wolves Hunting Wild Prey.** By L. David Mech, Douglas W. Smith, and Daniel R. Macnulty. 2015. The University of Chicago Press, 1427 East 60th Street, Chicago, IL, USA, 60637. 208 pages, 50.00 USD, Cloth.

BOTANY

Astounding Mushrooms. By Alain Bellocq. 2015. Firefly Books Ltd., 50 Staples Avenue, Unit 1, Richmond Hill, ON, Canada, L4B 0A7. 192 pages, 24.95 CAD, Cloth.

OTHER

Handbook of Road Ecology. By Rodney van der Ree, Daniel J. Smith, and Clara Grilo. 2015. Wiley-Blackwell, 10475 Crosspoint Boulevard, Indianapolis, IN, USA, 46256. 552 pages, 176.00 CAD, Cloth.

Evolution: Making Sense of Life, Second Edition. By Carl Zimmer, and Douglas Emlen. 2015. Roberts and Company Publishers, 7950 E. Prentice Avenue, Suite 206, Greenwood Village, CO, USA, 80111. 752 pages, 112.00 USD, Paper.

Evolution – the Whole Story. Edited by Steve Parker. 2015. Firefly Books Ltd., 50 Staples Avenue, Unit 1, Richmond Hill, ON, Canada, L4B 0A7. 576 pages, 39.95 CAD, Cloth.

The Carbon Bubble; What Happens to Us When It Bursts. By Jeff Rubin. 2015. Penguin Random House Canada, 90 Eglinton Avenue East, Suite 700, Toronto, ON, Canada, M4P 2Y3. 304 pages, 20.00 CAD, Cloth.

Hyper Nature. By Philippe Martin. 2015. Firefly Books Ltd., 50 Staples Avenue, Unit 1, Richmond Hill, ON, Canada, L4B 0A7. 176 pages, 39.95 CAD, Cloth.

News and Comment

New Light on the Origins of the Ottawa Field-Naturalists' Club

RANDY BOSWELL

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Boswell, Randy. 2015. New light on the origins of the Ottawa Field-Naturalists' Club. Canadian Field-Naturalist 129(2): 207–213.

The history of the Ottawa Field-Naturalists' Club (OFNC) is a subject of considerable interest given the organization's great longevity and significant influence on the evolution of Canadian science and conservation. A probe of 19th-century Ottawa newspapers has led to the proper identification of a little known precursor organization — the "Ottawa Naturalists' Field Club" — that appears to have significantly strengthened a weak link in the otherwise unbroken chain of natural history investigation in Ottawa reaching back to the pre-Confederation era. This and additional findings suggest that Dr. Edward Van Cortlandt, while duly recognized as an important pioneer naturalist, played an even greater role than generally understood in the emergence of a robust natural history tradition in Canada's capital and the eventual creation of the OFNC.

Key Words: Ottawa Field-Naturalists' Club; Ottawa Naturalists' Field Club; Ottawa Literary and Scientific Society; Ottawa Natural History Society; Ottawa Mechanics' Institute and Athenaeum; Edward Van Cortlandt; natural history; newspapers; journalism history

The establishment of the Ottawa Field-Naturalists' Club (OFNC) in March 1879 is a well-documented, landmark moment in the history of Canadian science (Brodo 1981; Brunton 2004; see also Brunton 2015, which references this study's central finding). As the most comprehensive chronicle of the life of the organization states, the OFNC's birth that year "launched careers, changed government policy, protected tens of thousands of hectares of Canadian natural landscape, produced internationally recognized and significant scientific publications, made huge contributions to our understanding and appreciation of North American natural sciences, and enriched thousands of lives" (Brunton 2004: 1).

The club also has what might be called a "prehistory," an embryonic phase of natural history activity in the Ottawa area reaching back to the 1850s that predates the establishment of the club and testifies to a well-rooted scientific interest in the local natural environment that eventually gave rise to the OFNC. The club came into existence as an off-shoot of a parent organization, the Ottawa Literary and Scientific Society (OLSS), after frustrations evidently arose among a number of OLSS members who believed that direct interaction with the natural world – through field trips beyond the city limits, first-hand observation of the region's plant and animal populations, and the collecting of floral, faunal, and geological specimens — was being overshadowed within the "culturally-oriented" OLSS by literary lectures held at a downtown meeting hall in Canada's increasingly urbanized and industrialized national capital. As Daniel F. Brunton's history of the OFNC noted, the club's founders wanted "to see more activity and greater opportunities being provided for natural environment investigations" (Brunton 2004: 5; see also Harrington 1909).

The purpose of this paper is to fill a gap in the historical record covering a key period in the evolution of Ottawa's natural history community between late 1869 and early 1871. The paper attempts to illuminate — as much as possible given the scant documentation that appears to have survived from this time — the people involved and the tensions that prevailed as the OFNC's precursor organizations struggled with financial and structural challenges while preserving a continuous commitment to natural history research that began at least as early as 1863.

The OLSS and Van Cortlandt

The OLSS (1869–1907) itself had evolved from two earlier organizations aimed at encouraging Ottawa's intellectual development: the Ottawa (formerly Bytown) Mechanics' Institute and Athenaeum (BMIA/OMIA, 1853–1869), and the Ottawa Natural History Society (ONHS, 1863–1869). The latter had broken off from the OMIA in 1863 over what appear to have been reasons similar to those cited by the founders of the OFNC in 1879. An even earlier entity, the more simply titled Bytown Mechanics' Institute (BMI), functioned from 1847 to 1849, but left few traces of its existence. It wasn't until after the organization was resurrected with an expanded name in 1853 that the OMIA played a significant role in Ottawa's intellectual development. Yet the earlier BMI appears likely to have planted an important seed that germinated a few years later.

Although the roots of the OFNC have been traced back along an "unbroken chain of organized, non-governmental natural history investigation" to the 1863 founding of the ONHS (Brunton 2004: 1), it is arguable that, as early as 1853, the Mechanics' Institute was providing an important outlet for investigating and recording aspects of the Ottawa area's natural history. So, too, was the allied Ottawa Silurian Society (OSS), an organization roughly contemporaneous with the OMIA and specifically devoted to studying the region's geological and paleontological riches.

At the centre of activity in each of these forerunners to the OFNC — in leading field trips, assembling and managing collections, donating specimens, maintaining libraries, delivering lectures, organizing exhibitions, publishing studies, identifying natural resource deposits, mentoring fellow enthusiasts, and promoting what might even be called a "proto-conservationist" ethic — was Dr. Edward Van Cortlandt (Figure 1), rightly described by Brunton as a "remarkably energetic man." Another of the three pioneer Ottawa naturalists identified by Brunton, paleontologist Elkanah Billings, named a fossil sea lily, *Carabocrinus vancortlandti,* after his friend and mentor, Dr. Van Cortlandt, "whose zeal in the advancement of science has been productive of many beneficial results," as Billings (1859: 32) wrote. In fact, Van Cortlandt had the unique distinction of having papers published by all three OFNC predecessors (BMIA, OSS, and ONHS) concerned with the natural history of the region (Van Cortlandt 1853a, 1860, 1867). Van Cortlandt also published what appears to be the first inventory of Ottawa-area animal species (Van Cortlandt 1859), a landmark archeological report (Van Cortlandt 1853b), and numerous other lectures and reports on the local environment, mostly in the columns of the *Ottawa Citizen.*

Establishment of the ONFC

Van Cortlandt must now also be credited with initiating a predecessor field club for nature-minded citizens, the Ottawa Naturalists' Field Club (ONFC), in 1870 — nearly a decade before the formation of the almost-identically named Ottawa Field-Naturalists' Club and at a time when the aforementioned unbroken chain was at its most tenuous.

The ONFC helped bridge the brief (less than a year) but critical period between the dissolution of the ONHS and the creation of the OLSS's natural history branch. The latter was formed only in October 1870, in apparent response to the creation earlier that year of Van Cortlandt's field club. Although having a fixed and apparently small number of members, the ONFC may have been seen as a potential competitor for the attention (and membership dues) of the capital's outdoorsy intellectuals.

The published and archival historical record of the OFNC does not document the existence of this earlier, Van Cortlandt-led organization. Its apparently brief flowering in 1870 nevertheless offered another clear indication that a perceived imbalance between purely theoretical, non-field-based pursuits and hands-on natural history investigation was present in 1870 in the months after the OLSS was officially launched following the merger of the ONHS and OMIA. This same concern seems to have led to the formation of the ONHS in 1863 and certainly prompted the creation of the OFNC in 1879.

FIGURE 1. Dr. Edward Van Cortlandt (1805–1875) was one of Bytown's first physicians and a leading figure in several societies devoted to the study of the natural history of the Ottawa area, including its plant and animal populations, natural resources, geological and paleontological features, and archeological traces.

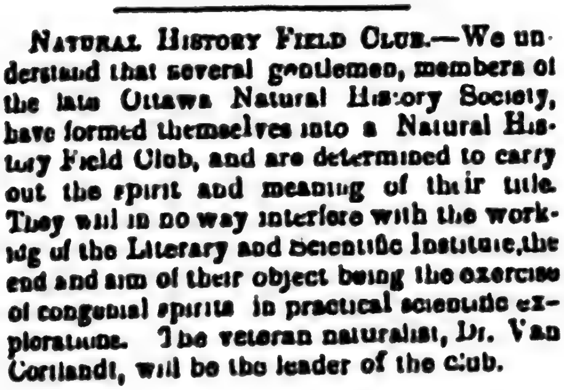
Evidence of the existence of the ONFC is found in a series of news items published in 1870 in the *Ottawa Citizen* and in a national directory of businesses and civic organizations published in 1871. This was an era when such organizations earned frequent and sometimes remarkably detailed press accounts of meetings, lectures, and field trips. In fact, by the mid-1850s, the *Ottawa Citizen* had become a particularly important outlet for communicating knowledge of and research into the Ottawa area's and Canada's natural history, principally because of Elkanah Billings' role as an editor of the paper in those years. His landmark launch in February 1856 of *The Canadian Naturalist and Geologist*, Canada's first scholarly journal "devoted exclusively to the study of Natural History," was a direct outgrowth of Billings' writings in the *Ottawa Citizen*, and was formally announced in the columns of the newspaper (Billings 1856).

In the case of the ONFC, however, press coverage of the group in 1870 is more slight and sporadic, perhaps suggesting a fragile association of members under Van Cortlandt's leadership that did not endure beyond its first year or so. Nevertheless, newspaper references to the club's formation offer additional evidence of an impulse within Ottawa's naturalist community to resist organizational changes that threatened to reduce opportunities for field research or diminished the perceived status of such work. And as stated above, there are indications that the ONFC's formation in January 1870 led the OLSS to launch its own natural history department that October. That initiative at least kept the torch of excursion-based research alight within the OLSS through the 1870s until it fully flamed with the birth of the OFNC in 1879.

Curiously, however, the journals of E. A. Meredith, who presided over and championed the 1869–1870 amalgamation of the ONHS and OMIA into the new OLSS (and whose archived writings at Library and Archives Canada are a well-known source of Ottawa history during this era), make no mention of any conflict over the amalgamation; nor do the archived records of the OLSS, held by the City of Ottawa Archives. Brunton (2004) has noted that the ONHS records from 1869 offer "surprisingly little" discussion of the amalgamation.

Although archived internal records, society-published pamphlets, and personal papers of club members can all be useful sources for tracing the histories of such 19th-century civic institutions, the era's newspapers also offer significant auxiliary information. Sometimes, as appears to be the case here, they reveal important facts that are otherwise absent from the documented past.

The first evidence that a new naturalists' field club had been organized in Ottawa in the wake of the ONHS's amalgamation with the OMIA is found in the 20 January 1870 edition of the *Ottawa Citizen* (Figure 2). The news brief introduced some confusion over the precise name of the new organization. It was made clear at this time, though, that the field club would "in no way interfere with the working of the Literary and Scientific Institute [i.e., OLSS], the end and aim of their object being the exercise of congenial spirits in practical scientific explorations" (Ottawa Citizen 1870a).



Natural History Field Club.—We understand that several gentlemen, members of the late Ottawa Natural History Society, have formed themselves into a Natural History Field Club, and are determined to carry out the spirit and meaning of their title. They will in no way interfere with the working of the Literary and Scientific Institute, the end and aim of their object being the exercise of congenial spirits in practical scientific explorations. The veteran naturalist, Dr. Van Cortlandt, will be the leader of the club.

FIGURE 2. This news brief appeared in the *Ottawa Citizen* on 20 January 1870, just one day after the newspaper carried a report of the official launch of the Ottawa Literary and Scientific Society (OLSS).

The ONFC and the OLSS

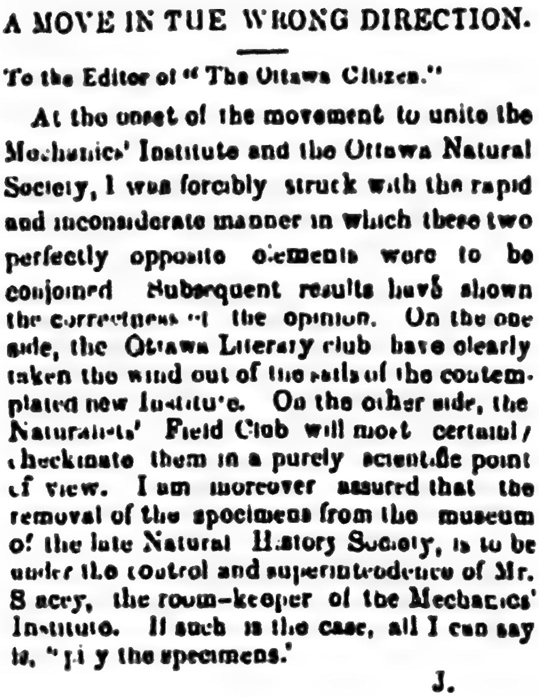
A few days later, it was reported under the headline "Naturalists Field Club" that "from the nature of this association, its membership is naturally limited; and we learn that its list of members is already completed. Arrangements will be made for a tramp in a comparatively short time" (Ottawa Citizen 1870b).

The timing of the news that this new club had been formed raises some interesting questions. It emerged just one day after the inaugural election of the officers of the newly formed OLSS (Ottawa Citizen 1870c). Was this a challenge to the new OLSS leadership? Intriguingly, Van Cortlandt was not among those who assumed executive positions, even though he had accepted reappointment as curator of the ONHS on 12 November 1869, the position he held during the entire existence of the ONHS, during the same meeting at which members discussed the amalgamation idea and ultimately decided to support it (Ottawa Citizen 1869a).

It appears that, in the opinion of Van Cortlandt and the "several gentlemen" who assembled themselves into the fledgling field club just two months later, the new OLSS was giving unacceptably short shrift to the scientific side of its mandate. This viewpoint evidently led Van Cortlandt to eschew involvement with the new group and to launch an independent organization devoted to "practical scientific explorations." This appears to have triggered a defensive response by the OLSS (its October 1870 inauguration of a natural history department). This parallels the tensions underlying the 1879 situation that led to the creation of the more specialized OFNC from within the membership of the OLSS.

Van Cortlandt was not the only observer of the situation unfolding in late 1869 and early 1870 who appeared to be concerned that something important might be lacking in the new OLSS. A week after the *Ottawa Citizen* reported the formation of the ONFC, a brief but pointed letter (Figure 3) by a writer identified only as "J." and headlined "A Move In The Wrong Direction" revealed simmering tensions over the amalgamation of the OMIA and ONHS into the OLSS and even concerns about its long-term viability: "At the onset of the movement to unite the Mechanics' Institute and the Ottawa Natural Society [sic], I was forcibly struck with the rapid and inconsiderate manner in which these two perfectly opposite elements were to be conjoined," the critic stated (J. 1870) "Subsequent results have shown the correctness of the opinion. On the one side, the [also recently organized] Ottawa Literary club have [sic] clearly taken the wind out of the sails of the contemplated new Institute. On the other side, the Naturalists' Field Club will most certainly checkmate them in a purely scientific point of view." The same writer predicted a sorry outcome — "pity the specimens" — for the newly combined museum collections of the two antecedent organizations.

There appears to have been no immediate response to J.'s public grumbling. However, subsequent news coverage contains additional indications of the field club's determination to endure, as well as signs of concern that the new OLSS might not survive. Responding to such concerns, its leaders took steps to improve the



A MOVE IN THE WRONG DIRECTION.

To the Editor of "The Ottawa Citizen."

At the onset of the movement to unite the Mechanics' Institute and the Ottawa Natural Society, I was forcibly struck with the rapid and inconsiderate manner in which these two perfectly opposite elements were to be conjoined. Subsequent results have shown the correctness of the opinion. On the one side, the Ottawa Literary club have clearly taken the wind out of the sails of the contemplated new Institute. On the other side, the Naturalists' Field Club will most certainly checkmate them in a purely scientific point of view. I am moreover assured that the removal of the specimens from the museum of the late Natural History Society, is to be under the control and superintendence of Mr. S acey, the room-keeper of the Mechanics' Institute. If such is the case, all I can say is, "pity the specimens."

J.

FIGURE 3. This letter, published in the *Ottawa Citizen* in late January 1870, expressed doubt that the newly formed Ottawa Literary and Scientific Society (OLSS) would survive, as a competitor literary club had recently been launched and Van Cortlandt's field club would "checkmate" the OLSS in terms of scientific research.

organization's prospects, including embracing a more conspicuous pursuit of natural history investigation.

On 12 April 1870 a letter to the *Ottawa Citizen* by "V.C." — unquestionably Van Cortlandt — begins: "Perhaps *de die in diem* you will admit the notes of the 'Ottawa Naturalist Field Club,' taken as the subjects present themselves." The note is crafted in classic Van Cortlandt style, the decorous Latin phrasing a signature feature of his newspaper correspondence and other writings. He follows with a series of observations about the return to Ottawa that week of several "spring birds," including white-breasted swallows [Tree Swallow] and the unexpectedly early "migratory thrush, *Tardus Migratorius* [sic]" — i.e., the American Robin — which "announced his coming ten days earlier than usual" (V. C. 1870).

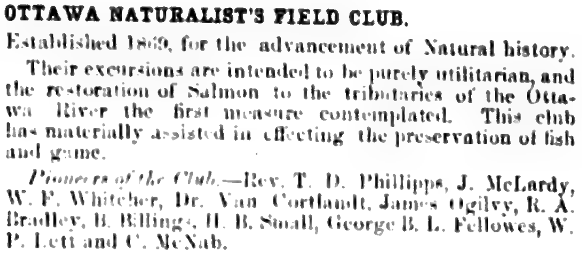
Two weeks later, the newspaper further reported that "we are assured that the members of the Ottawa Naturalists' Field Club intend that grass shall not grow under their feet" before an excursion "to the best spot for edification and research" is carried out — "so we have been informed by the leaders of the club" (Ottawa Citizen 1870d). The news item noted that the field trip would not be scheduled until the House of Commons rose for the summer, an indication that at least some of the members, as with all intellectual organizations in the city at that time, were federal public servants. There was also a reference to the club planning to have "departments" to be led by subject specialists, presumably in fields such as botany, entomology, paleontology, zoology, archeology, and so on.

Unfortunately, the local newspaper record is silent with regards to the ONFC's activities between May 1870 and January 1871, as no archived issues of the *Ottawa Citizen* exist for that period and other titles do not fill the gap in coverage. Surviving copies of a bilingual newspaper, *Le Courrier d'Outaouais/The Ottawa Courier*, do cover this period, but searches of this poorly preserved newspaper yielded no coverage of the OLSS or ONFC; similarly, issues of the *Ottawa Times* during these months offer no apparent coverage of the newly formed field club, though a series of three articles in November 1869 had made note of the ongoing negotiations to amalgamate the ONHS and OMIA and — with a viewpoint strongly shaped by Meredith's stated view that the two societies "were to a great extent Rival Societies" and would be "best served by their union" — the *Times* firmly encouraged such a merger (Ottawa Times 1869c; see also Ottawa Times 1869a and Ottawa Times 1869b).

However, a particularly illuminating piece of evidence documenting the existence of the ONFC is found in a publishing venture carried out in 1871 by the Montreal-based printer John Lovell. The 2,562-page *Lovell's Canadian Dominion Directory for 1871* includes an entry for the "Ottawa Naturalist's Field Club" (Figure 4) that lists the names of its 11 founding members — including "Dr. Van Cortlandt" — and a brief mission statement emphasizing the "purely utilitarian" aims of the organization, highlighting a project intended to achieve "the restoration of Salmon to the tributaries of the Ottawa River" (Lovell's 1871: 625).

The *Lovell's* entry identifies the following "Pioneers of the Club," an impressive group of individuals with strong links to the recently disbanded ONHS: Rev. Thomas D. Phillipps, a Church of England minister and assistant master at the Ottawa Grammar School who had served in executive positions with the ONHS (Vice-president 1865-1868 and Acting President Aug–Oct 1867); J. McLardy, almost certainly the man identified elsewhere in local history sources (see, for example, Ottawa Citizen 1869b) as Henry J. McLardy, a Presbyterian minister and founding secretary of Ottawa's first animal welfare organization, the Metropolitan Society for the Prevention of Cruelty to Animals, in 1871 (Ottawa Citizen 1871c); W. F. Whitcher, the federal government's powerful and sometimes controversial commissioner of fisheries (Whitcher 1872; Richardson 1880: 1153); James Ogilvy, a prominent Ottawa merchant and ONHS Treasurer (1865-1870); lawyer Richard Bradley; the inaugural (1863) ONHS president Braddish Billings, Jr., a notable Canadian botanist and entomologist identified by Brunton as one of Ottawa's three most important "pioneer resident naturalists" along with Billings' brother, Elkanah, and Van

Cortlandt; H. B. Small (1831-1919), civil servant and avid local naturalist who would author numerous books about natural history and who, with his son H. B. Small Jr. (1854-1949), the president of the Ottawa Field-Naturalists' Club in 1883, would be a founding member of the OFNC in 1879; George B. L. Fellowes, a lawyer and politician who would serve as Ottawa's mayor in 1876; William Pittman Lett, the longtime clerk of the City of Ottawa, who was also a local literary figure and prodigious chronicler of Bytown/Ottawa's early history as well as an executive member of the BMI (1848-49); and C. McNab who was presumably the county clerk Charles McNab.



OTTAWA NATURALIST'S FIELD CLUB.

Established 1869, for the advancement of Natural history.

Their excursions are intended to be purely utilitarian, and the restoration of Salmon to the tributaries of the Ottawa River the first measure contemplated. This club has materially assisted in effecting the preservation of fish and game.

***Pioneers of the Club.*—Rev. T. D. Phillipps, J. McLardy, W. F. Whitcher, Dr. Van Cortlandt, James Ogilvy, R. A. Bradley, B. Billings, H. B. Small, George B. L. Fellowes, W. P. Lett and C. McNab.**

FIGURE 4. An entry in *Lovell's Canadian and Dominion Directory for 1871* lists the founding members of the Ottawa Naturalists' Field Club and notes their intent to pursue "utilitarian" projects such as the restoration of salmon to the Ottawa River watershed.

The members of the newly formed (and ultimately short-lived) ONFC appeared to conflate — at least for the purposes of the *Lovell's* entry — the origins of their organization with a July 1869 salmon-stocking reconnaissance expedition to the confluence of the Ottawa and Salmon rivers at Montebello, Que., a mission carried out by three of the above gentlemen — Phillipps, McLardy and Van Cortlandt — under the auspices, in fact, of a "sub-committee" of the ONHS. According to a detailed report on the trio's July 19-20, 1869 trip to Montebello, located about 65 kilometres east of Ottawa, the Salmon showed "such promise of favorable results as regard its capabilities and value as a salmon breeding river, and a means of re-stocking the Ottawa and its tributaries with this incomparable attraction to the anglers and inestimable treat to the epicure" (Ottawa Citizen 1869b).

This well-documented undertaking was approvingly (though belatedly) referenced by Whitcher in his annual federal fisheries report for 1872, which detailed a number of artificial fish propagation and repopulation schemes across Canada and mapped out the planned restocking of the Salmon River under the direction of Samuel Wilmot, the Newcastle, Ont.-based pisciculturist who would go on to work with Whitcher for nearly 20 years as the federal superintendent of fish culture, pioneering Canada's fish hatchery system (Whitcher 1872; McCullough 1990).

More broadly, the salmon restoration project initiated by the ONHS "sub-committee" that evolved into the ONFC took place at a time when Van Cortlandt and other naturalists were colliding with industrial and political interests in the Ottawa area over the effects of sawdust pollution, viewed by Van Cortlandt as a threat not only to aquatic life but also to human health and navigation (Boswell 2014). This writer has elsewhere explored the steps taken in the 1860s by Van Cortlandt (initially in his capacity as Ottawa's medical officer of health) and Whitcher (as federal fisheries commissioner and Canada's top regulator of water quality in navigable streams) to curb the dumping of sawmill waste into the Ottawa River from the massive complex of mills at the Chaudière Falls just upstream from Parliament Hill. These efforts, alas, were largely unsuccessful (R. Boswell, unpublished document).

Among the other conservation activities previously undertaken by members of the fledgling ONFC was one in which Whitcher and Van Cortlandt had rather ingeniously collaborated to prevent the slaughter of snipe by Ottawa-area hunters. In April 1867, Van Cortlandt and Whitcher gained press coverage for their respective roles in a legal test case to foster the protection of insect-eating songbirds. Whitcher had apparently arranged with a local hunter — federal lands department clerk Frederick Austin — to allow himself to be charged with "shooting snipe contrary to law." While not specifically protected by game laws in Canada, the snipe, Whitcher would argue in court, should be declared off-limits to hunters under provisions of the "Insectivorous Birds Bill," legislation meant to protect songbird species that consume insects and, thus, help protect farmers' crops from pests. Van Cortlandt was called to the stand as an expert witness to give scholarly evidence that snipes do, in fact, eat insects. The case was decided in "prosecutor" Whitcher's favour, Austin was charged a token penalty of $1 and a legal precedent to make snipe-hunting illegal in Canada had been established (Ottawa Times 1867).

Whatever plans Van Cortlandt, Whitcher and their fellow naturalists had to continue pursuing such measures under an independent ONFC banner, the initiative appears to have fizzled out in 1871. In the spring of that year, the *Ottawa Citizen* reported a number of notable developments. First, Van Cortlandt, by then 65 years old, and destined to pass away in March 1875, had suffered a serious illness in early 1871, undoubtedly greatly undermining development plans for the ONFC (Ottawa Citizen 1871a). Furthermore, his fellow ONFC founder and Ottawa natural history "pioneer" Braddish Billings, Jr., would die in 1871, robbing the nascent group of an influential veteran figure in the study of the Ottawa area's natural environment.

Response by the OLSS

Meanwhile, at a meeting on 28 October 1870, the OLSS had established a naturalists' membership category with a mission to "complete the collection of objects illustrative of the Natural History of the Ottawa valley" (Ottawa Citizen 1871b). This move was evidently aimed at countering the creation of the ONFC and reassuring anyone inclined toward field research, specimen collection, and other hands-on scientific endeavours that such activities would be encouraged by the new society. Nevertheless, as of May 1871, the OLSS was still scrambling to enlist enough "life members" (at the hefty sum of $50 apiece) to cover its debts and ensure a stable future. One of the problems, the *Ottawa Citizen* reported at the time, was that "a good many members of the old Mechanics' Institute and Athenaeum and Natural History Society have not signed the new roll" (Ottawa Citizen 1871b).

Thus, although the 1869 amalgamation of the ONHS and OMIA "appears to have been seamless, with the members of the ONHS effectively becoming the Natural History Branch of the newly created OLSS" (Brunton 2004: 5), the newspaper record suggests it was more complicated than that. There is no sign in archived records or elsewhere that Van Cortlandt, so much a fixture of Bytown/Ottawa's successive nature-oriented organizations since 1853, ever joined the OLSS as an executive member, though the newspaper record shows that he did attend OLSS lectures on at least two occasions in December 1870 and Februrary 1871 when the topics involved paleontology and botany (Ottawa Times 1870; Ottawa Times 1871d). Yet it is clear that, for some period of time in 1870 and possibly beyond, he attempted to keep the spirit of the old ONHS alive by forming the Ottawa Naturalists' Field Club, although its role in the community may have been made moot soon after by the OLSS's creation of a natural history branch.

Emergence of the OFNC

The OLSS overcame its early difficulties in the years that followed and attracted a sufficient number of supporters, including those interested in field-based natural history studies, to endure into the 20th century. However, the OLSS structure never really did fully satisfy the needs of naturalists drawn to field trips, specimen gathering, and the presentation of original research about the Ottawa area's natural environment (Brunton 2004). OFNC founder W. H. Harrington recalled that, in 1878, James Fletcher "and a few kindred spirits [Harrington included] often discussed the possibility and necessity of reviving in Ottawa the scientific researches which had existed in earlier years" (Harrington 1909: 201). The factors driving that era's naturalists to launch their new club in 1879 were apparently presaged by Van Cortlandt and his field club peers nearly a decade earlier.

In December 1883, when reflecting in his inaugural address on the OFNC's early progress, newly installed president Dr. H. Beaumont Small, Jr. stated: "There is one point I would ask you to think over before the annual meeting, that is the name of the Club, which, I think, should be changed, so that it will read the Ottawa Naturalists' Field Club, instead of the Ottawa Field-Naturalists' Club. The change of a name is a serious matter always. Here it can hardly be called a change, rather an alteration, and in my opinion a correction" (Small 1884). Small was presumably alluding to Van Cortlandt's short-lived ONFC of 13 years earlier. His father, the distinguished naturalist H. B. Small, Sr., was an associate of Van Cortlandt and, as we now know from Lovell's directory, a member of the ONFC, although he was never listed as an ONHS member. Small Sr. may have recounted to his son the amalgamation controversy that spawned the ONFC in 1870.

Small's push for the OFNC to be renamed the Ottawa Naturalists' Field Club was not embraced. Yet this and other traces of the long-forgotten enterprise once championed by Van Cortlandt, promoter of just such an association for the "exercise of congenial spirits in practical scientific explorations," shine a light on this little known but significant phase in the evolution of the Ottawa Field-Naturalists' Club.

Conclusion

This paper details the January 1870 founding of the Ottawa Naturalists' Field Club, a previously undocumented precursor to the Ottawa Field-Naturalists' Club and a notable contributor to that storied organization's "unbroken chain" of naturalist activity extending back into pre-Confederation Canada. The paper also underscores the exceptional role of Dr. Edward Van Cortlandt in spearheading the creation of the ONFC, in participating in its inaugural project of attempting the reintroduction of salmon to the Ottawa River watershed, and in generally pioneering and promoting the study of the Ottawa area's natural history throughout the 1850s, 1860s and early 1870s.

This study, it might also be said, goes some way towards completing a research project envisioned in the pages of this journal more than 75 years ago by Aurèle LaRocque, a prominent Ottawa naturalist and OFNC member. Later a distinguished Ohio State University geologist who died an Emeritus Professor in 1990 (Hansen 1991), LaRocque noted in a 1939 review of J. R. Dymond's *Fishes of the Ottawa Region* (LaRocque 1939) that Van Cortlandt's early inventories of Ottawa fish species had proven valuable and been duly referenced in Dymond's volume, adding that: "The reviewer has collected a good deal of information concerning Dr. Van Cortlandt which he intends to include in an account of the beginnings of Natural History in the Ottawa region to appear later in *The Canadian Field-Naturalist*." That intended study was apparently never pursued; had it been, LaRocque might well have learned that Van Cortlandt, as shown here, did much to lay the foundations of the OFNC itself.

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Received 20 August 2014
Accepted 31 January 2015

Upcoming Meetings and Workshops

International Conference on Mycorrhiza

The 8th International Conference on Mycorrhiza, hosted by the International Mycorrhiza Society, to be held 3–7 August 2015 at Northern Arizona University's High Country Conference Center, Flagstaff, Arizona. The theme of the conference is: 'Mycorrhizal Integration across Continents and Scales'. Registration is currently open. More information is available at http://nau.edu/Merriam-Powell/ICOM8/.

Annual Symposium on the Conservation and Biology of Tortoises and Freshwater Turtles

The 13th Annual Symposium on the Conservation and Biology of Tortoises and Freshwater Turtles, hosted by the Turtle Survival Alliance and the International Union for Conservation of Nature Tortoise and Freshwater Turtle Specialist Group, to be held 6–9 August 2015 at the Westin La Paloma Resort, Tuscon, Arizona. Registration is currently open. More information is available at http://www.turtlesurvival.org/conference#.VVpOUC6YQeo.

Annual Phycological Society of America Meeting

The Annual Phycological Society of America Meeting to be held 8–13 August 2015 at Drexel University, Philadelphia, Pennsylvania. The theme of the meeting is: '50 for 50—Phycology in Philly', a celebration of the Journal of Phycology's 50th year of publication. Registration is currently open. More information is available at http://www.psaalgae.org/meetings/2015/8/8/2015-psa-annual-meeting.

Ecological Society of America Annual Meeting

The 2015 Ecological Society of America Annual Meeting to be held 9–14 August 2015 at the Baltimore Convention Center, Baltimore, Maryland. The theme of the conference is: 'Ecological Science at the Frontier: Celebrating ESA's Centennial', celebrating the Society's 100th year. Registration is currently open. More information is available at http://esa.org/baltimore/.

American Fisheries Society Annual Meeting

The 145th American Fisheries Society Annual Meeting, hosted by the Oregon Chapter and Western Division of the American Fisheries Society, to be held 16–20 August 2015 at the Oregon Convention Center, Portland, Oregon. Registration is currently open. More information is available at http://2015.fisheries.org/.

Northeast Partners in Amphibian and Reptile Conservation Meeting

The 2015 Northeast Partners in Amphibian and Reptile Conservation Meeting to be held 18–20 August 2015 at the Alton Jones Education Center of the University of Rhode Island, Greenwich, Rhode Island. Registration is currently open. More information is available at http://northeastparc.org/next-meeting-info/.

International Barcode of Life Conference

The 6th International Barcode of Life Conference, hosted by the International Barcode of Life project, to be held 18–21 August 2015 at the University of Guelph, Guelph, Ontario. The theme of the conference is: 'Barcodes to Biomes'. Registration is currently open. More information is available at http://dnabarcodes2015.org/.

Annual General Meeting of the Entomological Society of Ontario

The 152nd Annual General Meeting of the Entomological Society of Ontario to be held 18–20 September 2015 at the Queen's University Biological Station, Elgin, Ontario. More information is available at http://www.entsocont.ca/agm-2015.html.

International Conference on Ecology and Transportation

The 8th biennial International Conference on Ecology and Transportation, hosted by the North Carolina Department of Transportation with support from the U.S. Department of Transportation Federal Highway Administration, to be held 20–24 September 2015 at Raleigh Convention Center, Raleigh, North Carolina. The theme of the conference is: 'Roads to Resilience: Strengthening Essential Transportation and Ecological Assets across Diverse Landscapes'. Registration is currently open. More information is available at http://www.icoet.net/ICOET_2015/index.asp.

Student Conference on Conservation Science – New York

The 6th annual Student Conference on Conservation Science – New York, hosted by the American Museum of Natural History's Center for Biodiversity and Conservation and Yale University School of Forestry and Environmental Studies, to be held 7–9 October 2015 at the American Museum of Natural History, New York, New York. Registration is currently open. More information is available at http://www.amnh.org/our-research/center-for-biodiversity-conservation/events-exhibitions/conferences-and-symposia/2015-sccs-ny.

The Wildlife Society's Annual Conference

The 22nd annual conference of the Wildlife Society to be held 17–21 October 2015 at the RBC Convention Center, Winnipeg, Manitoba. Registration is currently open. More information is available at http://www.twsconference.org/.

Landmark decision halts Ostrander Wind Farm Project on the grounds of serious and irreversible harm to the Blanding's Turtle

A decision by the Court of Appeal for Ontario on April 20, 2015 upholds the landmark decision to halt the Ostrander Wind Farm Project on the grounds that the project would cause serious and irreversible harm to a threatened wildlife species: the Blanding's Turtle (*Emydoidea blandingii*). This decision was notable, because it was the first time that a renewable energy project, approved under the *Ontario Green Energy Act* and *Environmental Protection Act*, was overturned due to concerns for an at-risk species.

The Ostrander Wind Farm Project of the Ostrander Point Wind Energy LP was issued a Renewable Energy Approval by the Ontario Ministry of the Environment in December 2012. This project would involve construction of nine wind turbine generators, plus supporting infrastructure (including access roads), built on a 324-hectare area of crown land in Prince Edward County, Ontario.

Two local interest groups – the Prince Edward County Field Naturalists and the Alliance to Protect Prince Edward County – opposed this project, filing an appeal with the Environmental Review Tribunal. This appeal claimed that the Ostrander project should be stopped because it would cause serious harm to human health, and serious and irreversible harm to a variety of wildlife species and the natural environment, including birds, bats, butterflies, turtles, and alvar plants. In July 2013, the Renewable Energy Approval was revoked by the Environmental Review Tribunal. This landmark decision was nearly overturned; in February 2014 the Divisional Court set aside the Tribunal's decision, and reinstated the Renewable Energy Approval. This recent decision by the Court of Appeal for Ontario restores the Tribunal's decision, and halts the Ostrander Wind Farm Project.

Interestingly, the decision to halt the Ostrander Wind Farm Project was based solely on the Blanding's Turtle. The Tribunal rejected all claims of serious and irreversible harm to human health and wildlife, with the exception of the claim of serious and irreversible harm to the Blanding's Turtle. This Great Lakes population of the Blanding's Turtle is listed as threatened, both provincially (under the Ontario *Endangered Species Act*) and federally (under the *Species at Risk Act*). The Ostrander Wind Farm Project was determined to pose a serious and irreversible harm to this species because of the loss of habitat and road development, two of the major threats to this species. Blanding's Turtle is a biologically significant species; this is one of the longest-lived freshwater turtle species, and is the only living representative of its genus. This decision provides precedent for future renewable energy projects, suggesting that companies must seriously consider the potential risks their projects pose for wildlife species.

For further information, see: **Court of Appeal for Ontario.** 2015. Prince Edward County Field Naturalists v. Ostrander Point GP Inc., 2015 ONCA 269. Accessed 20 May 2015. www.ontariocourts.ca/decisions/2015/2015ONCA0269.htm.

Editor's Report for Volume 128 (2014)

One hundred and thirty-five years is a long time for any endeavour, but an unbroken record of independently publishing a scientific journal for this length of time by a non-profit organization is a remarkable feat. As the oldest natural history society in Canada, the Ottawa Field-Naturalists' Club has much to be proud of in its publication of *The Canadian Field-Naturalist* since 1880.

Volume 128 of *The Canadian Field-Naturalist* exemplifies the important role of this journal as a forum for dispersing science on the distribution, taxonomy, biology, behaviour, ecology, and conservation of species across a broad range of taxa in North America. In volume 128, topics included distribution of species from under-surveyed regions in Canada, population decline of species-at-risk, landscape ecology, ethology, migration, impact of drought and anthropogenic activities, habitat use, morphological variation, and improved methods for field biology. *The Canadian Field-Naturalist* also continued to publish tributes on the lives of remarkable naturalists, which remains an important contribution to natural history.

Mailing dates for issues in volume 128 are as follows: 26 March 2014; 8 July 2014; 20 October 2014; 30 January 2015. A summary of the distribution of memberships in the Ottawa Field-Naturalists' Club and subscribers to *The Canadian Field-Naturalist* for 2014 is provided in Table 1. Note that institutional subscribers represent many thousands of users. The number of articles and notes in Volume 128 is summarized in Table 2 by topic. Totals for book reviews and new titles is given in Table 3, and the distribution of content by page totals per issue is provided in Table 4. Seventy-seven manuscripts were submitted to *The Canadian Field-Naturalist* in 2014. Of these, 62 were accepted for publication. A total of 28 Articles, 14 Notes, and 3 Tributes were published in 2014.

Trina Rytwinski, Assistant Editor, edited content, acted as an occasional Associate Editor, and acted as Editor-in-Chief for over three months. Trina's adept management of the journal was invaluable. Elizabeth Morton and Sandra Garland proofed and edited manuscripts. We are grateful for the many years of excellent service that Elizabeth gave to the journal, and wish her well in her new endeavours. We also welcome Sandra Garland as the journal's new copy editor. Wendy Cotie typeset galleys, provided corrections for page proofs, and created pdfs; Roy John, Book Review Editor, requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings; Jay Fitzsimmons, Journal Manager, managed financial accounts, issue mailing, and requests for back issues, conducted journal promotion through Twitter and other means, and provided digital content to subscribers. William Halliday prepared the Index with proofreading by Frank Pope. Sandra Garland, webmaster of the Ottawa Field-Naturalists' Club, posted tables of contents, abstracts, and pdfs on the CFN section of the OFNC website. Our Associate Editors managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. The Publication Committee, chaired by Dan Brunton and consisting of Paul Catling, Jay Fitzsimmons, Sandra Garland, Tony Gaston, Karen McLachlan Hamilton, Frank Pope, and Jeff Saarela, effectively guided the operation of the journal. I am indebted to our very dedicated team.

The following Associate Editors managed, assessed and reviewed manuscripts published in volume 128: R. Anderson, Canadian Museum of Nature, Ottawa ON (1); F. R. Cook, Emeritus Research Associate, Canadian Museum of Nature, Ottawa ON (5); J. Foote, Algoma University, Sault Ste. Marie ON (10); A. J. Gaston, Environment Canada (emeritus), Ottawa ON (5); S. Jung, Yukon Government, Whitehorse YT (3); D. F. McAlpine, New Brunswick Museum, St. John NB (2); D. W. Nagorsen, Mammalia Biological Consulting, Victoria BC (5); C. Renaud, Canadian Museum of Nature, Ottawa ON (3); T. Rytwinski, Carleton University, Ottawa ON (2); J. Saarela, Canadian Museum of Nature, Ottawa ON (3); J. Skevington, Agriculture and Agri-Food Canada (3).

TABLE 1. The 2014 circulation of The Canadian Field-Naturalist (2013 in parentheses). Compiled by Ken Young from the subscription list for 128(4).

Subscriber Type	Canada		USA		Other		Total	
OFNC Members:								
Online	763	(714)	13	(15)	3	(3)	779	(732)
Printed	112	(89)	8	(8)	1	(1)	121	(98)
Subscriptions:								
Individual	78	(79)	28	(28)	3	(3)	109	(110)
Institutional	116	(127)	167	(159)	22	(28)	305	(314)
Total	306	(295)	203	(195)	26	(32)	535	(522)

TABLE 2. Number of research and observation articles and notes published in *The Canadian Field-Naturalist*, Volume 128, by major field of study.

Subject	Articles	Notes	Total
Mammals	5	7	12
Birds	12	3	15
Amphibians and Reptiles	5	0	5
Fish	2	1	3
Plants	1	2	3
Insects	0	1	1
Other	3	0	3
Total	28	14	42

TABLE 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, Volume 128, by topic.

	Reviews	New Titles
Zoology	28	49
Botany	5	5
Environment	4	0
Miscellaneous	5	29
Children	0	7
Total	42	90

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, Volume 128 (2014), by issue.

	Issue				
	1	2	3	4	Total
Editorials	0	3	0	0	3
Articles	71	78	37	89	275
Notes	12	18	16	0	46
Book Reviews*	19	10	19	15	63
News and Comment, Reports**	1	3	13	4	21
Tributes	7	0	19	0	26
Index				8	8
Total	110	112	104	116	442

*Includes reviews and new titles listings

**Includes CFN Editor's report, Minutes of the OFNC Annual Business Meeting, and OFNC Awards report.

The following referees reviewed manuscripts published in volume 128 (number of manuscripts reviewed >1 in parentheses): Ken Abraham, Ontario Ministry of Natural Resources (emeritus); Peter Achuff, Parks Canada (emeritus); Gary Anweiler, Edmonton AB; Sarah Baldo, University of Windsor; March Bechard, Boise State University; Robb Bennett, Royal British Columbia Museum Research Associate; Charles Blem, Virginia Commonwealth University (emeritus); Eric Benbow, Michigan State University; James Bogart, University of Guelph (emertius); Francois Bolduc, Canadian Wildlife Service, University of Quebec Rimouski; Rudy Boonstra, University of Toronto; Ronald J. Brooks, University of Guelph (emeritus); Syd Cannings, Canadian Wildlife Service; Leslie Carraway, University of Oregon; Suzanne Carriere, Northwest Territories Wildlife Division; Kristina Cockle, Louisiana State University; Peter Cott, Wilfred Laurier University; Robert Curry, Villanova University; Chris Darimont, University of Victoria; Jean-Francois Desroches, CEGEP Sherbrooke; Tony Diamond, University of New Brunswick; Anna Drake, Simon Fraser University; Brian Eaton, Alberta Innovates; Kerry Foresman, University of Montana; Charles Francis, Canadian Wildlife Service; Tony Gaston, Environment Canada (emeritius); John Gilhen, Nova Scotia Museum of Natural History; Scott Gillingwater, Upper Thames Conservation Authority; Laurie Goodrich, Hawk Mountain Sanctuary Association; Purnima Govindarajulu, British Columbia Ministry of Environment; Lee Grapentine, Environment Canada; Patrick Gregory University of Victoria; Peter Hall, Ottawa ON; Gary Hanes, Carleton Place ON; Stuart Houston, University of Saskatchewan (emeritus); David Howerter, Ducks Unlimited Canada; Gabriella Ibarguchi, Queens University; Samuel Iverson, Carleton University; Haley Kenyon, University of British Columbia; Erin Koen, Trent University; Don Lafontaine, Agriculture and Agri-Food Canada; Marcus Lashley, North Carolina State University; Ross Layberry, Fitzroy Harbour ON; Laurie Lee, Government of Nunavut; Jen Lento, University of New Brunswick; Jeremy Lundholm, Saint Mary's University; Carlos Ludica, Susquehanna University; Stephen MacDonald, University of New Mexico; Kris Maier, Gwich'in Renewable Resources Board; Mark Mallory, Acadia University; Donald McAlpine, New Brunswick Museum; Shannon McCauley, University of Toronto; Jim McLaughlin, Ontario Ministry of Natural Resources; Julie Moran-Ferron, University of Ottawa; Bob Montgomery, Queens University; Garth Mowat, Government of British Columbia; Dennis Murray, Trent University; Mark O'Donoghue, Yukon Department of Environment (2); Mike Oldham, Ontario Ministry of Natural Resources; Alexei M. Orlov, Russian Federation Research Institute of Fisheries and Oceanography; Jane Packard, Texas A&M University; Allysia Park, Saint Mary's University; Dave Prescott, Alberta Department of Fish and Wildlife, Environment and Sustainable Resource Development; Chuck Priestley, STRIX ecological consulting; Jamie Pinzon, University of Alberta; Rob Rempel, Ontario Ministry of Natural Resources; Greg Robertson, Environment Canada; Jeffery Rowell, Toronto ON; Brett Sandercook, Kansas State University; John Sauer, United States Geological Survey; Frederick W. Schueler, Bishop Mills Natural History Centre (3); Dave Seburn, Ottawa ON; Carolyn Seburn, Environment Canada; Fred Scott, Wildlife Museum Acadia University; Jeffrey Skevington, Agriculture and Agri-Food Canada; Jill Soha, Duke University; Bridget Stuchbury, York University; Tom Sullivan, University of British Columbia; Jon Swenson, Norwegian University of Life

Sciences; A. M. Tokranov, Russian Academy of Science; Karen Vanderwolf, Canadian Wildlife Federation; Jeroen Van Houdt, Royal Museum for Central Aftrica, Belgium; Joseph Veech, Texas State University; Richard Weir, British Columbia Ministry of Environment; Wayne Weller, Ontario Power Generation.

The journal was printed at Gilmore Printers, Ottawa. Thanks to Mike Datson of Gilmore Printers for overseeing production and printing. I am grateful to the Ottawa Field-Naturalists' Club President Fenja Brodo and the club's Council for their support of the journal. I am also grateful to all of the individual subscribers and authors who support our team as we strive to provide a high-quality scientific journal on natural history. Finally, we thank our families for being patient and supportive throughout many evenings and weekends of working on the journal.

CAROLYN CALLAGHAN
Editor in Chief

TRINA RYTWINSKI
Assistant Editor

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Mailing date of the previous issue 129(1): 5 May 2015

THE CANADIAN FIELD-NATURALIST Volume 129, Number 2 2015

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ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 129, Number 3 July–September 2015

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

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The Canadian Field-Naturalist

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COVER: Adult Ancient Murrelet *Synthliboramphus antiquus* taking off from the sea: Laskeek Bay, Haida Gwaii, British Columbia. See Gaston *et al.*, pages 285–289 in this issue. Photo: Ainsley Brown, Laskeek Bay Conservation Society.

The Canadian Field-Naturalist

Volume 129, Number 3 July–September 2015

Lichens in Four Newfoundland Provincial Parks: New Provincial Records

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McCarthy, John W., Kendra E. Driscoll, and Stephen R. Clayden. 2015. Lichens in four Newfoundland provincial parks: new provincial records. Canadian Field-Naturalist 129(3): 219–228.

Fieldwork in J. T. Cheeseman, Sandbanks, Jipujijkuei Kuespem, and Fitzgerald's Pond Provincial Parks, Newfoundland, has yielded 133 lichen taxa, of which 15 species are new to the province: *Anisomeridium biforme*, *Athallia holocarpa*, *Caloplaca borealis*, *Cetrelia olivetorum*, *Cladonia* cf. *rappii*, *Gyalolechia xanthostigmoidea*, *Lecanora straminea*, *Lecidea brunneofusca*, *Micarea globulosella*, *Micarea prasina* (*s.l.*), *Miriquidica pycnocarpa*, *Pertusaria consocians*, *Toensbergia leucococca*, *Usnea fragilescens* var. *mollis*, and *Usnea silesiaca*.

Key Words: Lichens; Newfoundland; provincial parks; new record; J. T. Cheeseman; Sandbanks; Jipujijkuei Kuespem; Fitzgerald's Pond

Introduction

The fundamental goals of a protected area system include maintaining biodiversity and natural processes and providing a location for scientific research that may guide management of the broader landscapes that surround the protected areas (Canadian Parks Council Climate Change Working Group 2013). To achieve these goals, it is important to gather information on species that occur within the protected areas and their associated habitats to obtain baseline data on existing natural diversity.

We report the results of a preliminary lichen survey of four provincially managed protected areas (provincial parks) in Newfoundland. This study represents the first survey of lichens in Newfoundland and Labrador provincial parks.

Methods

The survey was conducted in four provincial parks: J. T. Cheeseman Provincial Park, Port-aux-Basques, southwest Newfoundland; Sandbanks Provincial Park, Burgeo, south coast of Newfoundland; Jipujijkuei Kuespem Provincial Park, Bay d'Espoir, southeast Newfoundland; and Fitzgerald's Pond Provincial Park, Argentia, Avalon Peninsula (Figure 1).

Fieldwork was conducted between 23 June and 4 July 2009, using a floristic habitat sampling method (Newmaster *et al.* 2005) across the widest possible range of habitats. Habitat diversity was broadly assessed using a variety of resources including bedrock geology maps, surficial geology maps, National Topographic System 1:50 000 topographic maps, Earth Observation for Sustainable Development of Forest data, park maps, and communications with local park staff.

Table 1 details the major habitats surveyed in each provincial park. In at least one example of each identified mesohabitat in each park a "structured walkabout" or "intelligent meander" approach provided the freedom to explore lichen-rich sites in greater detail (Selva 1994; McMullin *et al.* 2008). After collecting the more common lichen species throughout the site, specific habitats were examined for specialist lichens. Microhabitats included coarse woody debris, streams, rock outcrops, cliffs, and tree bases. All fieldwork was carried out by J. W. M.

All lichens were identified and prepared for curation using standard herbarium techniques at the Botany and Mycology Section of the New Brunswick Museum (NBM), Saint John, New Brunswick. All voucher specimens have been deposited at the Provincial Museum of Newfoundland and Labrador with a select number of duplicates at NBM.

Given the limited scope and the time constraints on this reconnaissance survey (two days spent in readily accessible areas of each provincial park), search effort was necessarily limited. Only a small number of sites in each park were visited, and sampling at most sites was incomplete. Therefore, our results do not represent a comprehensive survey of lichen biodiversity in any of the four parks.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalist's Club.

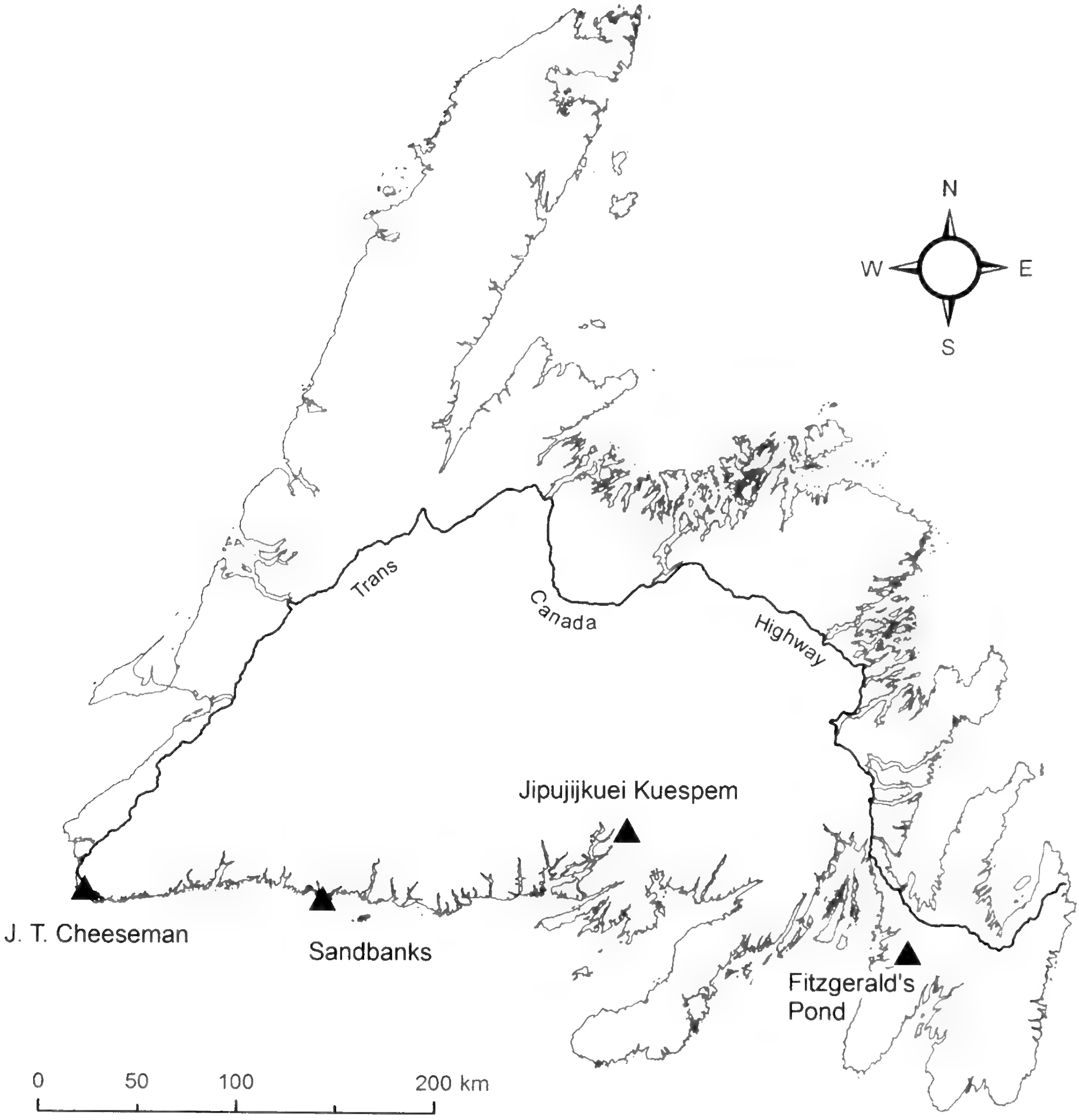

FIGURE 1. Map of Newfoundland showing the four provincial parks sampled for lichen biodiversity.

Results

Our study yielded 133 taxa, which are listed below. For each taxon, we give the habitat and location (Table 1) as well as the collection number of J. W. M. Records preceded by an asterisk are new records for Newfoundland. For each macrolichen, we summarize its status among the study areas using four categories of relative abundance: common (C), moderately common (MC), uncommon (U), and rare (R). These categories are based on the actual number of collections made during the study as well as the authors' knowledge of the relative abundance of macrolichens in Newfoundland. Unpublished records are indicated by the name of the collector followed by the herbarium where the collections are archived. Unpublished lichen records were provided by a search of the online database of the Consortium of North American Lichen Herbaria (CNALH n.d.) or through personal communication with those who identified particular specimens. For unpublished lichen records, herbaria accession numbers or collection numbers as well as the collection dates are provided. Lichen nomenclature follows Esslinger (2015) for the most part. Herbarium abbreviations follow Holmgren *et al.* (1981). Tree species abbreviations are as follows: bF = Balsam Fir (*Abies balsamea* (L.) Miller), bS = Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh), mA = American Mountain Ash (*Sorbus americana* Marshall), sA = Speckled Alder (*Alnus incana* ssp.), tL = Tamarack (*Larix laricina* (Du Roi)

TABLE 1. Habitats examined for lichen biodiversity in four Newfoundland provincial parks in 2009. Tree species abbreviations are as follows: bF = Balsam Fir (*Abies balsamea* (L.) Miller), bS = Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh), mA = American Mountain Ash (*Sorbus americana* Marshall), sA = Speckled Alder (*Alnus incana* ssp.), tL = Tamarack (*Larix laricina* (Du Roi) K. Koch), wB = Paper Birch (*Betula papyrifera* Marshall), wS = White Spruce (*Picea glauca* (Moench) Voss), yB = Yellow Birch (*Betula alleghaniensis* Britton).

Park and location	Survey date	Habitat	Latitude, °N, longitude, °W	Elevation, m
J. T. Cheeseman				
1A	June 24–25	Mature bF–wS–sA–mA stand	47.626–47.627, 59.271	17–29
1B	June 24–25	bS–bF–tL–*Cladonia*–Ericaceae-*Racomitrium*–*Betula* scrub–heath-bog complex	47.628, 59.243–59.245	39–46
1C	June 25	Conifer–heath scrub on granite outcrop	47.633, 59.258	22–25
1D	June 25	Mature bF–wS–wB–sA stand	47.633, 59.255	16–18
1E	June 25	Mature bS–bF–mM–*Dryopteris* stand	47.632–47.633, 59.256	14–15
1F	June 25	bS scrub	47.630, 59.268	35–37
1G	June 25	Mature bF–wS stand	47.628, 59.267	9
1H	June 26	*Scirpus* bog with *Cladonia*–*Sphagnum* hummocks	47.630, 59.265	25
Sandbanks				
2A	June 27	Mature wS–bF herb-rich stand	47.603, 57.647–57.648	3–11
2B	June 27	Mature bF–wS herb-rich stand	47.602–47.603, 57.652	2–3
2C	June 27	Ericaceae–*Cladonia* heath on sand dunes	47.605–47.606, 57.646	7–10
2D	June 27	bF herb-rich stand	47.602–47.603, 57.649–57.650	5–9
2E	June 28	sA–bF–wS scrub on *Empetrum*–*Cladonia*–Ericaceae heath-covered sand dunes	47.607–47.609, 57.652–57.654	4–8
2F	June 28	*Empetrum*–*Potentilla* granite headland	47.608, 57.656	10–13
2G	June 28	Ericaceae–*Racomitrium* heath on granite outcrops	47.604, 57.654–57.655	18–42
Jipujijkuei Kuespem				
3A	June 30	Mature bF–yB–wB–wS–*Dryopteris* stand	47.909–47.910, 55.604–55.606	160–178
3B	July 1	bS–Ericaceae stand	47.906, 55.575	163–165
3C	July 1	*Cladonia*–*Racomitrium*–tL heath on rock outcrop	47.905, 55.585	137–142
3D	July 1	Semi-mature bF–tL feathermoss–*Sphagnum* stand	47.906–47.907, 55.591	141–147
3E	July 1	bF–bS–wB–feathermoss stand	47.917, 55.571–55.572	154–158
3F	July 1	bS scrub–bog/fen	47.904–47.906, 55.586–55.589	134–160
Fitzgerald's Pond				
4A	July 3	Ericaceae–*Cladonia*–bF–bS–tL scrub	47.332–47.333, 53.746	178–180
4B	July 3	*Cladonia*–Ericaceae–*Racomitrium* rocky heath	47.335, 53.744	167–183
4C	July 3	bF–bS–tL–wS Ericaceae–*Cladonia* complex	47.334, 53.743–53.744	150–169
4D	July 3	Ericaceae–*Scirpus*–*Cladonia*–conifer scrub heath	47.332–47.335, 53.745–53.746	178–189
4E	July 4	Mature bF–bS–*Sphagnum* feathermoss stand	47.331–47.333, 57.743–57.746	164–173
4F	July 4	Mature bF–wB–*Dryopteris* stand	47.328–47.331, 53.744–53.746	132–157

K. Koch), wB = Paper Birch (*Betula papyrifera* Marshall), wS = White Spruce (*Picea glauca* (Moench) Voss), yB = Yellow Birch (*Betula alleghaniensis* Britton).

Annotated Species List

Alectoria sarmentosa (Ach.) Ach. ssp. *sarmentosa* (C) — Corticolous on dead and live bF branch, dead wB twig, and bS branch. 2D *1090*; 3A *1094*; 4C *1034*; 4E *1114*.

Alectoria sarmentosa ssp. *vexillifera* (Nyl.) D. Hawksw. (U) — Terricolous on sandy dune soils. 2C *1170*.

**Anisomeridium biforme* (Borrer) R.C. Harris — Corticolous on yB stem. 3A *1188*. This record is noteworthy as a northward extension of a mainly temperate species (Harris 1973).

Arctoparmelia centrifuga (L.) Hale (C) — Saxicolous on granite and schist. 2G *1023*; 3C *1194*.

Arctoparmelia incurva (Pers.) Hale (U) — Saxicolous on siliceous rock. 4D *1141*.

**Athallia holocarpa* (Hoffm.) Arup, Frödén & Søchting — Corticolous on wS branch and on dead bF twig. 2E *1238*, *1267A*. Grows on various enriched rocks, mortar, concrete and on bark and wood of many tree species. Temperate to boreal–arctic, widespread. Recorded for southeastern Labrador (Thomson 1997). Unpublished Newfoundland records include James C. Lendemer from the central Avalon Peninsula (*NY-00954676, 2007*) and from the Great Northern Peninsula (*NY-00973015, 2007*) and Arthur C. Waghorne from central Newfoundland (*NY-00975213, 1894)*.

Biatora helvola Körb. ex Hellb. — Corticolous on yB stem. 3A *1257B*. Printzen and Tønsberg (1999) considered the occurrence of *B. helvola* in North America to be doubtful. Previously, this name was widely applied to most corticolous, non-sorediate *Biatora* specimens with beige to red-brown, convex apothecia. Reports of *B. helvola* for eastern North America are referable mainly to *B. longispora* or *B. pycnidiata* (Printzen and Tønsberg 2004). In contrast to *B. helvola s. str.*, both of these species lack gyrophoric acid in the apothecia and thallus. The three species can also be distinguished on the basis of pycnidial and ascospore characters. Spribille *et al.* (2009) confirmed the presence of *B. helvola* in Alaska. Our collection from the island of Newfoundland and other unpublished records from the neighbouring Maritime Provinces indicate that this species has a bicoastal distribution in North America. That said, Printzen (2014) found that *B. helvola* as currently circumscribed still appears to be heterogeneous.

Biatora pycnidiata Printzen & Tønsberg — Corticolous on moss-covered bF stem, wS stem, dead wS branch, and dead bF stem. 1A *1271*; 1D *1269*; 2A *1251*; 2E *1054*, *1254B*. Corticolous crustose lichen on twigs and trunks of conifers and deciduous trees. Although common in eastern North America, *B. pycnidiata* was described only recently (Printzen and Tønsberg 2004); the type specimen was collected on bark of *Abies balsamea* near Bay Bulls, south of St. John's, Newfoundland.

Bryoria americana (Motyka) Holien (C); syn. *B. trichodes* subsp. *americana* (Motyka) Brodo & D. Hawksw. — Corticolous on dead bF branch. 1A *1162*.

Bryoria furcellata (Fr.) Brodo & D. Hawksw. (C) — Terricolous on sandy soil and corticolous on tL branch. 2C *1195*; 3F *1235*.

Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw. (MC); syn. *B. lanestris* (Ach.) Brodo & D. Hawksw. — Corticolous on bF branch. 4C *1066*.

Bryoria nadvornikiana (Gyeln.) Brodo & D. Hawksw. (U) — Corticolous on dead bF branch. 2D *1077*.

Bryoria trichodes (Michx.) Brodo & D. Hawksw. (C) — Corticolous on dead bF stem, dead bF twig, wB stem, and bF stem. 1A *1171*; 2A *1095*; 3A *1205*; 4E *1100*.

**Caloplaca borealis* (Vain.) Poelt — Corticolous on dead wS branch. 2E *1254A*. Corticolous crustose lichen with a circumboreal distribution and occurring mainly on smooth-barked deciduous trees (Wetmore 2007). Wetmore (2007) noted the presence of *C. borealis* in Newfoundland; however, the collection supporting this record (*I. M. Brodo 8818, MIN-893893, 1966*) is from the Menihek Lake area of western Labrador (Cliff Wetmore, personal communication, 16 July 2013).

Cetraria aculeata (Schreb.) Fr. (MC) — Terricolous on sandy dune and heath duff. 2C *1028*, *1195*; 4D *1059*.

Cetraria islandica subsp. *crispiformis* (Räsänen) Kärnefelt (C) — Terricolous on heath and sandy dune duff. 1B *1107*; 1C *1062*; 2C *1211*; 2E *1116*, *1233*; 4D *1013*.

Cetraria muricata (Ach.) Eckfeldt (MC) — Terricolous on heath duff. 1B *1098*, *1121*; 3C *1215*; 4D *1119*.

**Cetrelia olivetorum* (Nyl.) W.L. Culb. & C.F. Culb. (R) — Corticolous on yB stem. 3A *1014*. On broadleaved trees or mossy rocks in temperate and montane forests of the northern hemisphere, particularly in eastern North America, western Europe, and eastern Asia, but also in South America, Africa, and Australia. Unpublished records from the Avalon Peninsula include Stephen R. Clayden (*NBM-FL-11529, 2005*) and John W. McCarthy (*NBM-FL-13547, 2008*). The lack of older records may suggest that *C. olivetorum* is a recent colonist in Newfoundland. However, it is somewhat similar in appearance to the very common *Platismatia glauca* and might have been overlooked. In any case, it appears to be restricted to mature *Abies–Picea* forests characterized by a significant component of *Betula alleghaniensis*.

Cladonia amaurocraea (Flörke) Schaer. (C) – Terricolous on heath duff and among mosses. 1B *1123*, *1214*; 1C *1144*; 2G *1227*; 4B *1036*.

Cladonia arbuscula (Wallr.) Flot. (C) — Terricolous among mosses on bog, on heath duff on rock and sandy soil. 1B *1182*; 1C *1210*; 2C *1217*, *1229*; 3F *1213*; 4D *1039*, *1126*. *Cladonia arbuscula* subsp. *mitis* (Sandst.) Ruoss is not considered here as *C. mitis* Sandst. is accepted as a distinct taxon (Brodo *et al.* 2001; Ahti and McCarthy 2013).

Cladonia boryi Tuck. (C) — Terricolous on heath duff and sandy dune soil. 1B *1153*; 2C *1146*; 3C *1159*; 4B *1065*.

Cladonia cenotea (Ach.) Schaer. (C) — Terricolous on bog, corticolous on bF coarse woody debris on ground. 3F *1074*; 4F *1022*, *1085*; 4E *1225*.

Cladonia chlorophaea (Flörke ex Sommerf.) Spreng. *s. str.* (C) — Corticolous on wS stem. 1A *1109*.

Cladonia coccifera (L.) Willd. (C) — Terricolous on heath duff on rock and soil. 3C *1049*; 4B *1038*, *1040*.

Cladonia crispata (Ach.) Flot. (C) — Terricolous on duff on rock and soil, corticolous on bF coarse woody debris. 2E *1224*; 3C *1076*, *1218*; 4D *1051*, *1055*, *1064*, *1088*; 4F *1045*, *1085*.

Cladonia cristatella Tuck. (C) — Terricolous on heath duff on soil, corticolous on dead, sloughing bF coarse woody debris. 4D *1106*; 4F *1021A*.

Cladonia cyanipes (Sommerf.) Nyl. (UC) — Terricolous on heath duff on soil. 2C *1104*; 3C *1228*.

Cladonia gracilis (L). Willd. subsp. *gracilis* (C) — Terricolous on heath duff and among mosses. 1B *1011*, *1216*; 3C *1190*; 4D *1015*.

Cladonia gracilis subsp. *turbinata* (Ach.) Ahti (R) — Terricolous on heath duff on rock. 4D *1020*.

Cladonia grayi G. Merr. ex Sandst. (C) — Corticolous on dead bF stem, terricolous on heath duff on rock. 2A *1212*; 3E *1031*; 4D *1024*, *1032*.

Cladonia macilenta Hoffm. (C) — Corticolous on dead bS and bF coarse woody debris. 3E *1031*; 4F *1021B*.

Cladonia maxima (Asahina) Ahti (C) — Terricolous on sandy dune soils and among mosses. 2C *1083*; 2G *1199*; 2E *1232*.

Cladonia ochrochlora Flörke (C) — Terricolous among mosses, corticolous on dead bF, bS, and wS bark and roots. 1A *1061*, *1122*, *1203*; 2A *1148 1158*; 2B *1086 1165*; 3E *1031*; 4E *1507*.

Cladonia rangiferina (L.) F. H. Wigg. (C) — Terricolous on heath duff, among mosses. 1B *1118*; 1F *1026*; 2C *1134*; 2E *1226*; 3B *1157*; 4D *1060*.

**Cladonia* cf. *rappii* A. Evans (R) — Terricolous on moss duff in rock crevice. 4B *1071*. *Cladonia rappii s. str.* resembles the much more common *C. verticillata*. It differs in possessing a larger number of tiers of centrally proliferating podetial cups, in the often early breakdown and disappearance of its basal squamules and in developing blackened podetial bases spotted with pale senescent areoles. It also differs ecologically. In Atlantic Canada, *C.* cf. *rappii* is confined to oceanic areas mainly in bogs or on peaty soil over rock; *C. verticillata* occurs throughout the region, mainly on mineral soil in habitats such as heathlands, old fields, roadsides, and rocky outcrops.

Cladonia squamosa Hoffm. (C) Terricolous on duff on rock and ground, corticolous on bF and bS, often moss-covered stem. 1A *1124*, *1178*; 1B *1128*, *1160*; 1C *1230*; 2A *1017*, *1197*; 2B *1165*; 2D *1177*; 2G *1135*; 3D *1187*; 3E *1058*; 4D *1033*, *1052*, *1069*; 4E *1225*; 4F *1145*.

Cladonia stellaris (Opiz) Pouzar & Vězda (C) - Terricolous on heath duff. 1B *1140*; 2C *1111*; 3B *1108*; 4D *1048*.

Cladonia straminea (Sommerf.) Flörke (U); syn. *Cladonia metacorallifera* Asahina — Terricolous on duff in granite rock depression. 2G *1132*.

Cladonia stygia (Fr.) Ruoss (C) – Terricolous on heath duff. 1B *1092*; 2E *1009*; 3C *1193*; 4D *1041*.

Cladonia terrae-novae Ahti (C) — Terricolous on heath and forest floor duff. 1F *1184*; 1H *1156*; 4D *1039*, *1075*.

Cladonia uncialis (L.) F. H. Wigg. (C) — Terricolous on bog and heath duff on soil and rock. 1B *1056*, *1204*; 2C *1161*; 3C *1025*, *1149*; 4B *1057*.

Cladonia verticillata (Hoffm.) Schaer. (MC) — Terricolous on heath duff on granite. 2G *1220*.

Cladonia wainioi Savicz (C) — Terricolous on heath duff. 1B *1125*; 3C *1138*; 4B *1030*.

Coccocarpia palmicola (Spreng.) Arv. & D. J. Galloway (U) — Corticolous on bF stem. 4E *1174*.

Degelia plumbea (Lightf.) P. M. Jørg. & P. James (R) — Corticolous on yB stem. 3A *1198*. In 2010, designated as of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010). This lichen is considered rare in Newfoundland with nine known occurrences in the humid mature forests of the Central Avalon Peninsula and the Bay d'Espoir region of the island's southeast coast.

Evernia mesomorpha Nyl. (U) — Corticolous on dead bF and wS branch and twig. 1A *1189*; 2A *1166*.

Fuscopannaria ahlneri (P. M. Jørg.) P. M. Jørg. (U) — Corticolous on yB stem. 3A *1102*.

**Gyalolechia xanthostigmoidea* (Räsänen) Søchting, Frödén & Arup — Corticolous on yB stem. 3A *1257A*. First described by Räsänen (1933) as *Placodium xanthostigmoidea* based on corticolous *Betula*, *Abies*, and *Thuja* material from New Brunswick. This species grows on a variety of substrates and is widespread in cool regions of the northern hemisphere (Wetmore 2001). Unpublished records include James C. Lendemer (*NY-00965264, 2006; 00974491-00974496, 2007*) from the Great Northern Peninsula.

Graphis scripta (L.) Ach. Corticolous on yB stem. 3A *1042*.

Hypogymnia incurvoides Rass. (C) — Corticolous on bF and bS stem, dead bF stem and dead wB stem. 1E *1152*; 2A *1237*; 3A *1099*; 4E *1063*.

Hypogymnia physodes (L.) Nyl. (C) — Corticolous on dead bF, wS, and wB twig, branch, and stem; saxicolous on arkose rock. 1B *1073*; 2A *1079*; 3A *1053*; 4A *1155*.

Hypogymnia tubulosa (Schaer.) Hav. (C) — Corticolous on dead bS, wS, and tL twig and branch. 1B *1150*; 2A *1231*; 4C *1008*.

Hypogymnia vittata (Ach.) Parrique (MC) — Corticolous on bF dead branch and live stem. 2A *1087*; 4E *1105*.

Icmadophila ericetorum (L.) Zahlbr. — Terricolous on soil duff and lignicolous on decayed conifer stump. 2G *1273*; 3D *1192*.

Imshaugia aleurites (Ach.) S.L.F. Mey. (C) — Lignicolous on dead decorticate bF stem and branch stub. 4E *1223*; 4F *1080*.

Japewia tornoënsis (Nyl.) Tønsberg — Corticolous on tL twig and dead bS branch. 1B *1046B*, *1142*. Published distribution maps show occurrences of this species in western Labrador (Thomson 1997) and on the Avalon Peninsula (Brodo *et al.* 2001).

Lasallia papulosa (Ach.) Llano (C) — Saxicolous on granite. 1B *1219*; 2G *1136*.

Lecanora cinereofusca H. Magn. — Corticolous on dead and live yB branch and stem. 3A *1241A*, *1257A*, *1261*.

Lecanora dispersa (Pers.) Sommerf. *s.l.* — Corticolous on wS branch. 2E *1238*.

Lecanora pulicaris (Pers.) Ach. — Corticolous on dead mA stem. 1D *1253B*.

**Lecanora straminea* Ach. — Saxicolous on granite. 2F *1191*. This lichen is often found on bird-enriched coastal rocks, circumpolar in the northern hemisphere. It occurs in southeast Labrador (Thomson 1997; Ryan 1998) and Miquelon (Le Gallo 1952). Unpublished Newfoundland records include James C. Lendemer (*NY-00966854, 2007*) on limestone/dolostone from the Great Northern Peninsula.

Lecanora symmicta (Ach.) Ach. — Corticolous on tL twig, bS branch, and dead wS and bF twigs. 1B *1046A*, *1142*, *1244*; 2A *1079*; 2E *1267A*, *1267B*.

Lecidea albofuscescens Nyl. — Corticolous on bF stem. 1A *1240*.

**Lecidea brunneofusca* H. Magn. — Saxicolous. 4A *1275*. This lichen grows on granitic rocks and is endemic to northeastern North America (Magnusson 1935; Brodo *et al.* 2001).

Lichinodium sirosiphoideum Nyl. (U) — Corticolous on bF stem. 4E *1029*.

Lobaria pulmonaria (L.) Hoffm. (C) — Corticolous on yB stem. 3A *1139*.

Lobaria quercizans Michx. (U) — Corticolous on yB stem. 3A *1221*.

Lobaria scrobiculata (Scop.) DC. (MC) — Corticolous on mA stem. 3A *1047*.

Lopadium disciforme (Flotow) Kullh. — Corticolous on wS and bF stem. 1D *1269*; 4E *1239A*, *1019*; 4F *1247*.

Loxospora cismonica (Beltram.) Hafellner — Corticolous on bF stem. 1A *1264*. All published records for this lichen are from the Avalon Peninsula and eastern Newfoundland (Maass 1980; Brodo *et al.* 2001).

Loxospora elatina (Ach.) A. Massal. — Corticolous on dead and live bF stem. 1A *1245*, *1248*; 4E *1242*, *1265*, *1270*; 4F *1272*.

Loxospora ochrophaea (Tuck.) R. C. Harris — Corticolous on bF and bS stems. 1A *1256*; 1E *1259*.

Melanelixia fuliginosa (Fr. ex Duby) O. Blanco *et al.* (C) — Corticolous on bF and yB stems. 1A *1181*; 3A *1042*.

Menegazzia terebrata (Hoffm.) A. Massal. (U) — Corticolous on yB stem. 3A *1050*. Widespread in temperate northern hemisphere. Found in sheltered, productive *Abies balsamea–Betula alleghaniensis* forests. Recorded from Fogo Island (Deduke and Piercey-Normore 2013; Piercey-Normore 2013). Unpublished records include James C. Lendemer (*NY-00954686, 2007*) and Richard C. Harris (*NY-00961418, 2007*) from *Abies balsamea–Picea mariana–Betula* forests in the central Avalon Peninsula.

**Micarea globulosella* (Nyl.) Coppins — Corticolous on bF stem. 4E *1239B*. In Canada, this apparently rare, but small and perhaps overlooked, lichen has been recorded for Quebec (Coppins 1983) and Fundy National Park, New Brunswick (Gowan and Brodo 1988). It seems to favour humid, old coniferous forests (Coppins 1983).

Micarea peliocarpa (Anzi) Coppins & R. Sant. — Corticolous on dead wS branch. 2E *1054*.

**Micarea prasina* Fr. *s.l.* — Corticolous on dead bF branch and on bF, wS and yB stems. 2A *1262*; 2D *1077*; 3A *1097B*; 4E *1266*. This lichen is extremely variable and thin-layer chromatography is required for certain separation from several other *Micarea* species (Coppins 2009). Unpublished records include James C. Lendemer (*NY-00954698, 2007*) from *Picea mariana–Abies balsamea–Betula* forests of the central Avalon Peninsula and Arthur C. Waghorne (*MIN-18162, 1897*) from western Newfoundland.

**Miriquidica pycnocarpa* (Körb.) M.P. Andreev — Saxicolous. 4A *1275*. Found on coarse-grain siliceous rocks, particularly granites. First reported for Canada (Nova Scotia) by MacDonald *et al.* (2011). Unpublished records include William R. Buck (*NY-00944256-00944257, 2007*) and Richard C. Harris (*NY-00961351, 2007*) from rocky montane to subalpine oceanic heath on the Avalon Peninsula.

Mycoblastus affinis (Schaer.) T. Schauer — Corticolous on bF stem. 4E *1239A*.

Mycoblastus caesius (Coppins & P. James) Tønsberg — Corticolous on bF stem. 4E *1239A*, *1252*.

Nephroma arcticum (L.) Torss. (U) — Terricolous on moss-covered rock face. 2D *1131*.

Nephroma laevigatum Ach. (U) — Corticolous on yB stem. 3A *1202*.

Normandina pulchella (Borrer) Nyl. (R) — Corticolous on yB stem. 3A *1097A*. Recorded in humid coniferous forests in the Avalon Peninsula (COSEWIC 2010). Cosmopolitan, but rarely collected in Newfoundland. Generally found on mosses and other lichens in humid forests.

Ochrolechia androgyna (Hoffm.) Arnold — Corticolous on bF stem. 4E *1268*.

Ochrolechia frigida (Sw.) Lynge — Terricolous on duff, corticolous on coarse woody debris. 2G *1258*; 4D *1263*; 4F *1274*.

Parmelia omphalodes (L.) Ach. (C) — Saxicolous on granite. 2G *1127*.

Parmelia saxatilis (L.) Ach. (C) — Saxicolous on exposed bedrock. 1B *1180*.

Parmelia squarrosa Hale (C) — Corticolous on stems of dead wB, dead and live bF. 1A *1067*; 2A *1185*; 3A *1183*; 4E *1091*.

Parmelia sulcata Taylor (C) — Saxicolous on coastal granite headland and on arkose rock. 2F *1130*; 4D *1010*.

Parmeliella parvula P.M. Jørg. (U) — Corticolous on bF stem. 4E *1029*, *1209*. Widespread but scattered in cool temperate regions of both northern and southern hemispheres. In Newfoundland, currently known only from conifers in humid conifer forests of the central Avalon Peninsula (Hinds and Hinds 2007; Jørgensen *et al.* 2009).

Parmeliella triptophylla (Ach.) Müll. Arg. (U) — Corticolous on yB stem. 3A *1097A*.

Parmeliopsis ambigua (Wulfen) Nyl. (U) — Corticolous on bS stem and branch. 3F *1200*.

Parmeliopsis capitata R.C. Harris ex J.W. Hinds & P.L. Hinds (C) — Corticolous on dead bS and live bF branch. 1B *1179*; 4C *1035*, *1137*.

Parmeliopsis hyperopta (Ach.) Arnold (C) — Corticolous on dead bS branch, bS branch and stem, and bF branch. 1B *1142*, *1173*; 3F *1120*, *1200*; 4C *1035*.

Peltigera membranacea (Ach.) Nyl. (MC) — Terricolous on sandy dune. 2A *1103*.

Peltigera neopolydactyla (Gyeln.) Gyeln. (C) — Corticolous on the base of bF stem. 4F *1101*.

**Pertusaria consocians* Dibben — Corticolous on dead yB branch. 3A *1241B*. Endemic to the Appalachian–Great Lakes region of North America (Dibben 1980) including the Maritimes (Gowan and Brodo 1988).

Pertusaria macounii (I.M. Lamb) Dibben — Corticolous on dead yB branch. 3A *1241B*.

Pertusaria waghornei Hulting — Corticolous on yB stem. 3A *1257A*. First collected in 1894 by Arthur C. Waghorne at Whitbourne, Avalon Peninsula on trunks of *Betula* sp. (Hulting 1896). Corticolous on hardwoods, west to the Great Lakes Region, and south along the Appalachians (Dibben 1980).

Physcia tenella (Scop.) DC. (C) — Corticolous on wS branch and saxicolous on granite. 2E *1238*; 2F *1196*.

Platismatia glauca (L.) W.L. Culb. & C.F. Culb. (C) — Corticolous on dead bF branch, live bF stem, and live bS branch. 1A *1089*; 2D *1077*; 2A *1222*; 3B *1151*; 4E *1019*.

Platismatia norvegica (Lynge) W.L. Culb. & C.F. Culb. (MC) — Corticolous on dead bF branch and on bF stem. 2A *1175*; 3D *1129*; 4C *1018*; 4E *1093*.

Plastismatia tuckermanii (Oakes) W.L. Culb. & C.F. Culb. (R) — Corticolous on dead tL branch. 3D *1096*. Found throughout the Great Lakes Appalachian region of North America, but rare in Newfoundland (Clayden 2010).

Polycauliona polycarpa (Hoffm.) Frödén, Arup & Søchting (MC) — Corticolous on wS twig and branch. 2C *1115*; 2E *1238*.

Porpidia tuberculosa (Sm.) Hertel & Knoph — Saxicolous. 4A *1275*.

Pseudocyphellaria perpetua McCune & Miadl. (R) — Corticolous on yB stem. 3A *1188*. Known from oceanic and suboceanic regions in North America and the Russian Far East (Miadlikowska *et al.* 2002). Previously recorded from Newfoundland by Högnabba *et al.* (2009).

Pycnothelia papillaria Dufour (MC) — Terricolous on ground and on duff on granite. 2G *1250*; 3C *1215*.

Pyrenula laevigata (Pers.) Arnold — Corticolous on yB stem. 3A *1260*. First recorded for Newfoundland as *Pyrenula glabrata* (Eckfeldt 1895).

Pyrrhospora varians (Ach.) R.C. Harris — Corticolous on bF dead twig. 2E *1267A*. The only other Newfoundland records date from the late 19th century and early 20th century (Eckfeldt 1895) as *Biatora varians*, as well as recent collections on *Betula alleghaniensis* in western Newfoundland (McCarthy *et al.* 2013).

Ramalina farinacea (L.) Ach. (C) — Corticolous on bF dead twig. 2A *1147*.

Ramalina roesleri (Hochst. ex Schaer.) Hue (C) — Corticolous on bF dead branch and twig, wS dead twig, wS twig and branch, bF stem, and tL dead branch. 1G *1169*; 2A *1163*; 2C *1115*; 2E *1238*, *1267A*; 3E *1154*; 4C *1027*.

Rinodina freyi H. Magn. — Corticolous on wS branch and bF dead twig. 2E *1238*, *1267A*. One of the most frequently collected *Rinodina* species in North America (Sheard 2010).

Ropalospora chlorantha (Tuck.) S. Ekman — Corticolous on bF stem. 1A *1271*.

Scoliciosporum chlorococcum (Stenh.) Vězda — Corticolous on bF dead twig. 2E *1267B*.

Sphaerophorus fragilis (L.) Pers. (C) — Saxicolous on granite. 1B *1117*.

Sphaerophorus globosus (Huds.) Vain. (C) — Corticolous on wS dead stem; terricolous on duff on granite; corticolous on bF dead branch stub, and conifer coarse woody debris on ground. 2A *1168*; 2F *1110*; 4E *1234*, *1225*.

Stereocaulon dactylophyllum Flörke (MC) — Saxicolous on arkose rock. 4B *1044*.

Stereocaulon vesuvianum Pers. (C) — Saxicolous on arkose rock. 4B *1016*.

Thelotrema lepadinum (Ach.) Ach. — Corticolous on yB stem. 3A *1097A*.

Thelotrema suecicum (H. Magn.) P. James — Corticolous on mA dead stem. 1D *1253A*. Rarely collected in Newfoundland. Known from southwestern Newfoundland (Esslinger and Egan 1995) and collected by James C. Lendemer (*NY-1409400-1409401, 2006*) from Gros Morne National Park, western Newfoundland, and by Richard C. Harris (*NY-00961422, 00961424; 2007*) from the *Abies balsamea–Betula alleghaniensis* forests of the central Avalon Peninsula.

**Toensbergia leucococca* (R. Sant.) Bendiksby & Timdal; syn. *Hypocenomyce leucococca* R. Sant. and *Pycnora leucococca* (R. Sant.) R. Sant. — Corticolous on bF branch, bF dead twig and on bS and wS dead branch. 1B *1142*; 2E *1054*, *1267C*; 4C *1035*. Reported by Brodo (1991) from the Menihek Lake region of western Labrador. Otherwise, much overlooked and rarely reported for North America (Spribille and Björk 2008). Unpublished records include Teuvo Ahti (*H-2501a, 2946, 2968b, 6284b, 7734a, 8802a, 8807a, 8957c, 9047, 9881a; 1956 and 34905a; 1978*) throughout Newfoundland.

Trapeliopsis granulosa (Hoffm.) Lumbsch — Terricolous on duff in granite rock depression. 2G: 1255.

Tuckermannopsis americana (Spreng.) Hale (C) — Corticolous on tL live and dead twig and branch. 1B: *1046A*; 3B: *1112*; 4C: *1008*, *1037*.

Tuckermannopsis orbata (Nyl.) M.J. Lai (MC) — Corticolous on bF branch and on bF live and dead twigs. 2E: *1012*; 3E: *1201*; 4E: *1043*.

Umbilicaria muehlenbergii (Ach.) Tuck. (C) — Saxicolous on granite rock. 2G *1176*.

Umbilicaria polyphylla (L.) Baumg. (C) — Saxicolous on granite rock. 2G *1167*.

Usnea dasopoga (Ach.) Nyl. (C); syn. *U. filipendula* Stirt. — Corticolous on bF dead twig and live wB stem. 1A *1207*; 3A *1084A*.

**Usnea fragilescens* var. *mollis* (Vain.) Clerc (U) — Corticolous on wB stem. 3A *1084B*; 4F *1133*. An unpublished record (as *Usnea fragilescens* Hav. ex Lynge) is James C. Lendemer (*NY-00954691, 2007*) on conifer in *Abies balsamea–Picea mariana–Betula* forests in the central Avalon Peninsula.

Usnea longissima Ach. (MC) — Corticolous on bF dead twig, live and dead branches. 2A *1081*; 3A *1208*; 4C *1068*; 4E *1070*.

**Usnea silesiaca* Motyka (MC) — Corticolous on bF dead and live stem, wB stem. 2B *1172*; 3A *1078 1084C*; 4F *1082*, *1113A*, *1113B*. Unpublished records include Teuvo Ahti (*H-6267, 8495; 1956*), Stephen R. Clayden (*NBM-FL-11683, 2005*), I. Mackenzie Lamb (FH-00079189, 1953), and John W. McCarthy (N*BM-FL-13542, 13543; 2011; NBM-FL-13545, 13548, 13708; 2008*) from the Avalon Peninsula.

Usnea subfloridana Stirt. (UC) — Corticolous on bF dead branch. 1A *1143*. Recorded for Newfoundland by Thomson (2009). Unpublished records include James C. Lendemer (*NY-00954827, 00954842, 00954843; 2007*) and Teuvo Ahti (*H-2665b, 6266, 9188; 1956*) from the Avalon Peninsula.

Variolaria pustulata (Brodo & W.L. Culb.) Lendemer, Hodkinson & R.C. Harris — Corticolous on dead yB branch. 3A *1241C*. Thomson (2009) reported it from Newfoundland, but gave no details.

Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai (C) — Corticolous on bS and wS dead branches and on bF live branch. 1B *1173*; 2E *1054*; 4C *1035*.

Acknowledgements

Financial support for this survey was provided by Parks and Natural Areas Division and Wildlife Division, Newfoundland and Labrador Department of Environment and Conservation. Trevor Goward (Beatty Biodiversity Museum, University of British Columbia) helped in the development of the sampling protocol. Crystal Breon, geographic information system specialist with Parks and Natural Areas prepared Figure 1. Mike Drew, Ross Hinks, and Fred Hinks of the Department of Natural Resources, Miawpukek First Nation, Conne River, Newfoundland, warmly welcomed J. W. M. to Jipujijkuei Kuespem Provincial Park. We thank park managers Bill LeFrense (J. T. Cheeseman), Derrick Mercer (Sandbanks), and Nehemiah Pinsent (Jipujijkuei Kuespem) for logistical support. We extend a special thank you to those who permitted citation of their unpublished lichen records: Teuvo Ahti, Finnish Museum of Natural History, University of Helsinki; William Buck, Richard Harris, and James Lendemer, New York Botanical Garden; and Cliff Wetmore, Bell Museum of Natural History, University of Minnesota. Two reviewers significantly improved the quality of the manuscript.

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Received 26 December 2013
Accepted 30 March 2015

Distribution and Use of Brood-rearing and Moulting Sites of the Atlantic Population of Canada Geese (*Branta canadensis*) in Nunavik, Quebec

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Cotter, Richard C. 2015. Distribution and use of brood-rearing and moulting sites of the Atlantic population of Canada Geese (*Branta canadensis*) in Nunavik, Quebec. Canadian Field-Naturalist 129(3): 229–236.

The Atlantic population of Canada Geese (*Branta canadensis*) nests in the coastal lowlands of eastern Hudson Bay and southwestern Ungava Bay in Nunavik, Quebec. Although many aspects of the nesting ecology of this and other northern populations of Canada Geese have been studied and published, there is a paucity of information on the use of brood-rearing and moulting sites. Based on 18 years of band and recapture data from an ongoing banding program, this paper presents the distribution of brood-rearing and moulting sites and the use of these sites over time. Along Hudson Bay and Ungava Bay, the most important brood-rearing and moulting areas are the stretch of coastal lowlands between the Mariet River and Shallow Bay and between Rivière aux Feuilles and Virgin Lake, respectively. Of all adult geese captured during the banding program (n = 41 924), 7.5% (standard error [SE] 0.13%) were recaptures, that is, birds that had previously been caught and banded; annual recapture rates ranged from 5.1% to 11.4%. The mean and median distances between the site of first recapture and the original site of capture were 4.3 km (SE 0.22 km) and 1.5 km, respectively. Juveniles moved, on average, 5.4 km farther than adults and males moved 1.4 km farther than females. Among geese banded as juveniles, males moved twice as far as females: 11.5 km versus 5.7 km.

Key Words: Canada Goose; *Branta canadensis*; Atlantic population; brood-rearing; moulting areas; dispersal; Nunavik; Quebec; Hudson Bay; Ungava Bay

Introduction

The Canada Goose (*Branta canadensis*) is one of North America's most widely distributed waterfowl species, as it nests in a broad range of habitats, including urban areas, prairie parklands, boreal forests, and taiga and tundra regions. Although the life history of the Canada Goose has been well studied (see review by Mowbray *et al.* 2002), there have been few studies of tundra-nesting populations because of the relatively high associated costs. Notable exceptions are the studies of populations of *B. canadensis interior* nesting along western Hudson Bay, Ontario; on Akimiski Island in James Bay, Nunavut; and in Nunavik, Quebec (Bruggink *et al.* 1994; Leafloor *et al.* 2000; Gan 2012; Cotter *et al.* 2013, 2014).

Although it is known that groups of flightless moulting Canada Geese are found in the same areas each summer (e.g., Sterling and Dzubin 1967) and that geese can show high fidelity to nesting areas (Cooke *et al.* 1975; Lindberg *et al.* 1995), there are few published quantitative data on repeat use and faithfulness to brood-rearing and moulting sites. Previous use and the familiarity of such sites can provide ecological advantages to birds, such as improved feeding efficiency and knowledge of predators, but faithfulness to areas with deteriorating habitat conditions may be maladaptive (Lindberg and Sedinger 1998). The Atlantic population of Canada Geese nests exclusively in Quebec (Cotter *et al.* 2013; Rodrigue 2013) and has been the subject of an ongoing program, in which moulting family groups have been banded annually since 1997 (Cotter 2015). Each year, 5–11% of all adult geese captured have been captured and banded in a previous year (hereafter called recaptures).

The objective of our study was to identify key brood-rearing and moulting areas, as well as to quantify distances between locations of first capture (and banding) and recapture of geese to help assess the importance of moulting areas to the Atlantic population of Canada Geese. Such information can help wildlife agencies manage and monitor this population on the breeding grounds more cost effectively and provide baseline data on the use of these areas by Canada Geese for environmental impact studies.

Study Area

The coastal areas of eastern Hudson Bay and southwestern Ungava Bay support the highest densities of the breeding Atlantic population of Canada Geese (Malecki and Trost 1990; Harvey *et al.* 2014). Both areas are located in the Southern Arctic Ecozone and are characterized by lower relief, numerous potholes and ephemeral ponds, herb–lichen tundra, and a cold, dry climate (Malecki and Trost 1990; Wiken *et al.* 1996).

Methods

Each year during 1997–2014, from late July to mid-August, four- to five-person crews searched these coastal areas (lowlands) by helicopter (Bell 206 Long Ranger, Bell Helicopter Textron Inc., Fort Worth, Texas, USA; and Eurocopter AS-350 A-Star and EC130, Airbus Helicopters, Marignane, France) for brood flocks of

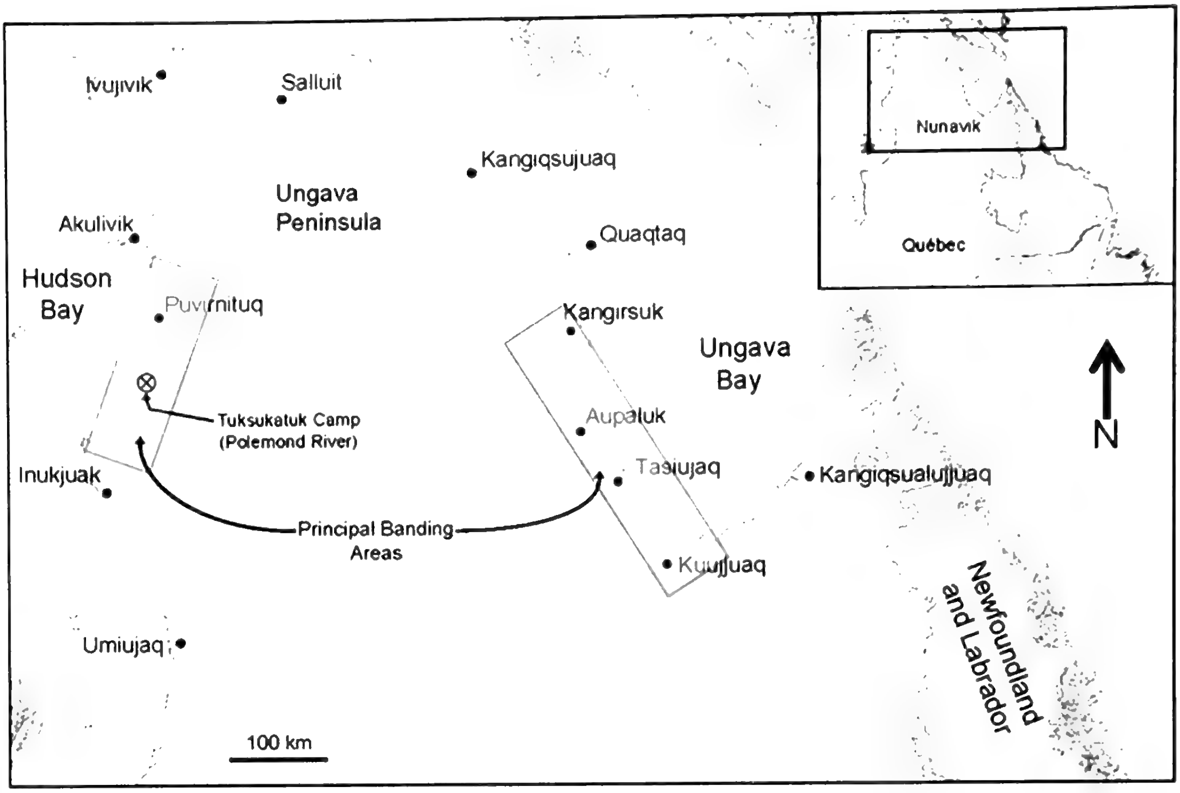

FIGURE 1. Map of the Ungava Peninsula, northern Quebec, showing the location of the Hudson Bay and Ungava Bay lowlands where banding of Atlantic population Canada Geese (*Branta canadensis*) was carried out from 1997 to 2014.

geese to capture and band (Figure 1). By the time of banding, adult geese had moulted their remiges and were flightless, and goslings were 4–6 weeks old.

Brood flocks ranging from 20 to 80 birds (both adults and goslings) were captured using a technique similar to Heyland (1970) and Leafloor and Rusch (1997). Each captured goose was fitted with a standard numbered United States Fish and Wildlife Service aluminium leg band, and the age (adult: after-hatch year [AHY]; juvenile: gosling) and sex (determined from cloacal examination) were recorded for all individuals. For adult females, the presence or absence of a brood patch was also recorded, with presence indicative of females that had laid eggs that year (Hanson 1959). Geographic coordinates (universal transverse mercator [UTM]) for each catch site were determined using a Garmin handheld Global Positioning System unit (models 48 and 76, Garmin, Olathe, Kansas, USA).

Along Hudson Bay, the base of operations was Tuksukatuk Camp, located on the Polemond River, although fuel and supplies were purchased at Puvirnituq, 60 km to the north (Figure 1). Two helicopters and crews operated simultaneously, except in 1997 and 2012–2014 when only one helicopter and crew banded. Each year, each crew banded for an average of nine days and flew 25 hours. All catch sites were located between the coast and approximately 50 km inland and between the Inuit communities of Inukjuak and Akulivik (Figure 1), but most sites were between the Mariet (59°9'N) and Sorehead (60°31'N) rivers (Figure 2).

Banding effort over the various areas of the lowlands for moulting family groups was fairly consistent among years, with the following two exceptions. First, between 1997 and 2003, in a 32.8 km^2 area along the Polemond River, an intensive nesting ecology study of Atlantic population Canada Geese was carried out (described in Cotter *et al.* 2013). Part of this study included web-tagging goslings at hatching and recapturing them during the banding operations to calculate gosling survival rate. Consequently, in these years, extra time and effort was expended by the banding crew in this area to catch as many family groups (and web-tagged goslings) as possible. Second, the area between Puvirnituq and the Sorehead River was not searched systematically but, instead, the crew flew in a fairly straight line between those locations, because of range and fuel concerns, although at a sufficiently low altitude and speed to detect family groups.

Along Ungava Bay, a single crew was based at either Kuujjuaq (1997–2011) or Aupaluk (2012–2014); each year, this crew banded on average for nine days and flew 33 hours. All catch sites were located between Kangiqsualujjuaq (on the George River) (58°42'N, 65°57'W) and the Virgin Lake area (60°8'N), approximately 15 km northeast of Kangirsuk (Figure 1). The main banding area (representing > 95% of all catches), however, extended from Qikirtajuaq Island (also known as Big Island), located at the mouth of Rivière à la

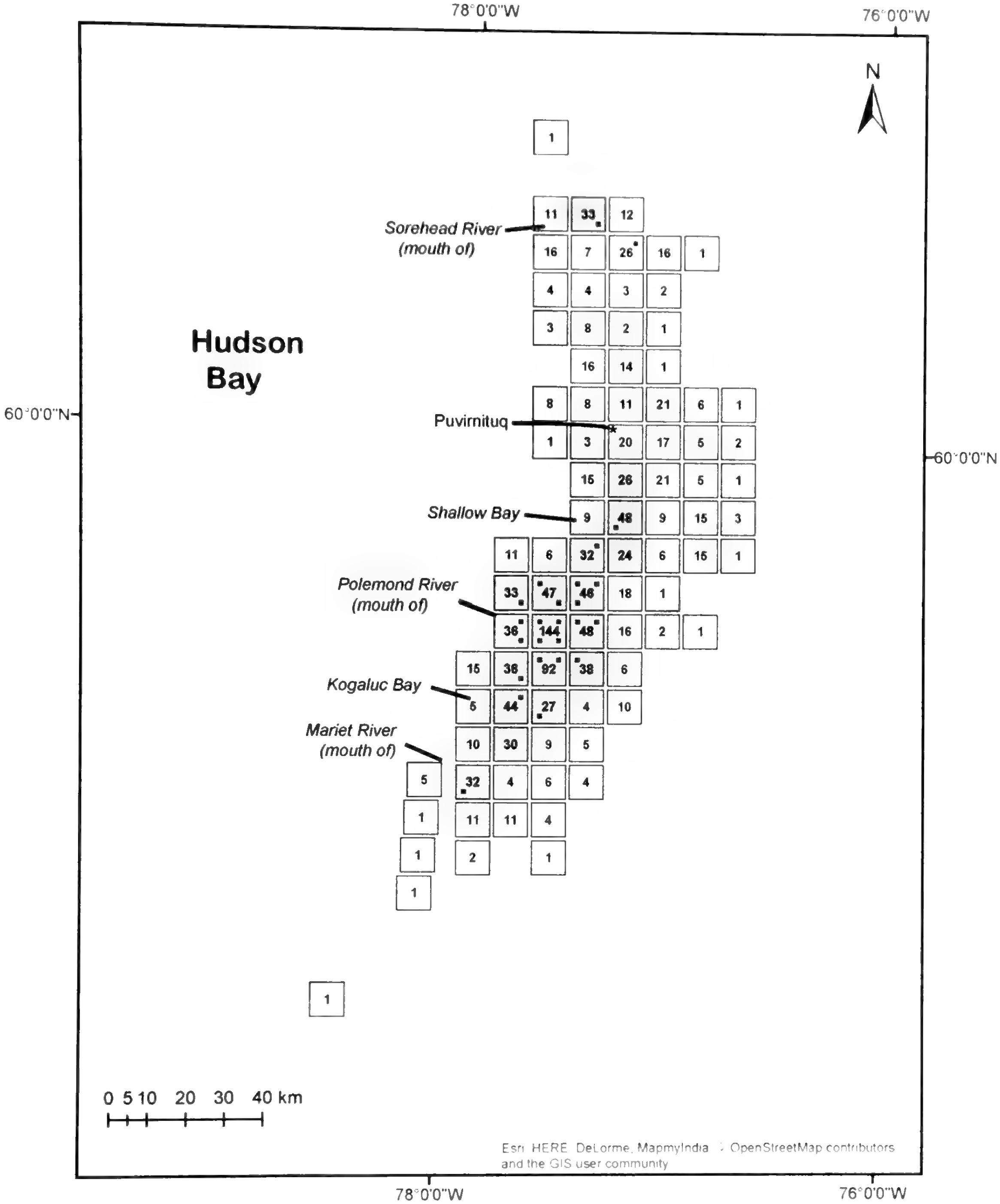

FIGURE 2. Map of Hudson Bay, northern Quebec, with distribution of 10 km × 10 km squares where Atlantic population Canada Geese (*Branta canadensis*) were captured and banded from 1997 to 2014. The number inside each square is the total number of catches made over the 18-year period. Squares in which geese were captured in 12 or more years are shaded grey. Quadrants (25 km^2), within a square, in which geese were captured in nine or more years are indicated as small black square symbols.

Baleine, to the Virgin Lake area (Figure 3). In the 1990s, Qikirtajuaq Island was a major nesting and banding area, but, in the early 2000s, American Black Bears (*Ursus americanus*) began preying heavily on goose nests, with the consequence that, by 2005, few geese were nesting on the island (Cotter *et al.* 2014). To compensate for the loss of this important nesting, and hence banding, site, crews increased their banding effort north of the Rivière aux Feuilles and ceased operations east of Rivière à la Baleine entirely, as it became inefficient to use helicopter time to work in this area which had lower brood flock densities.

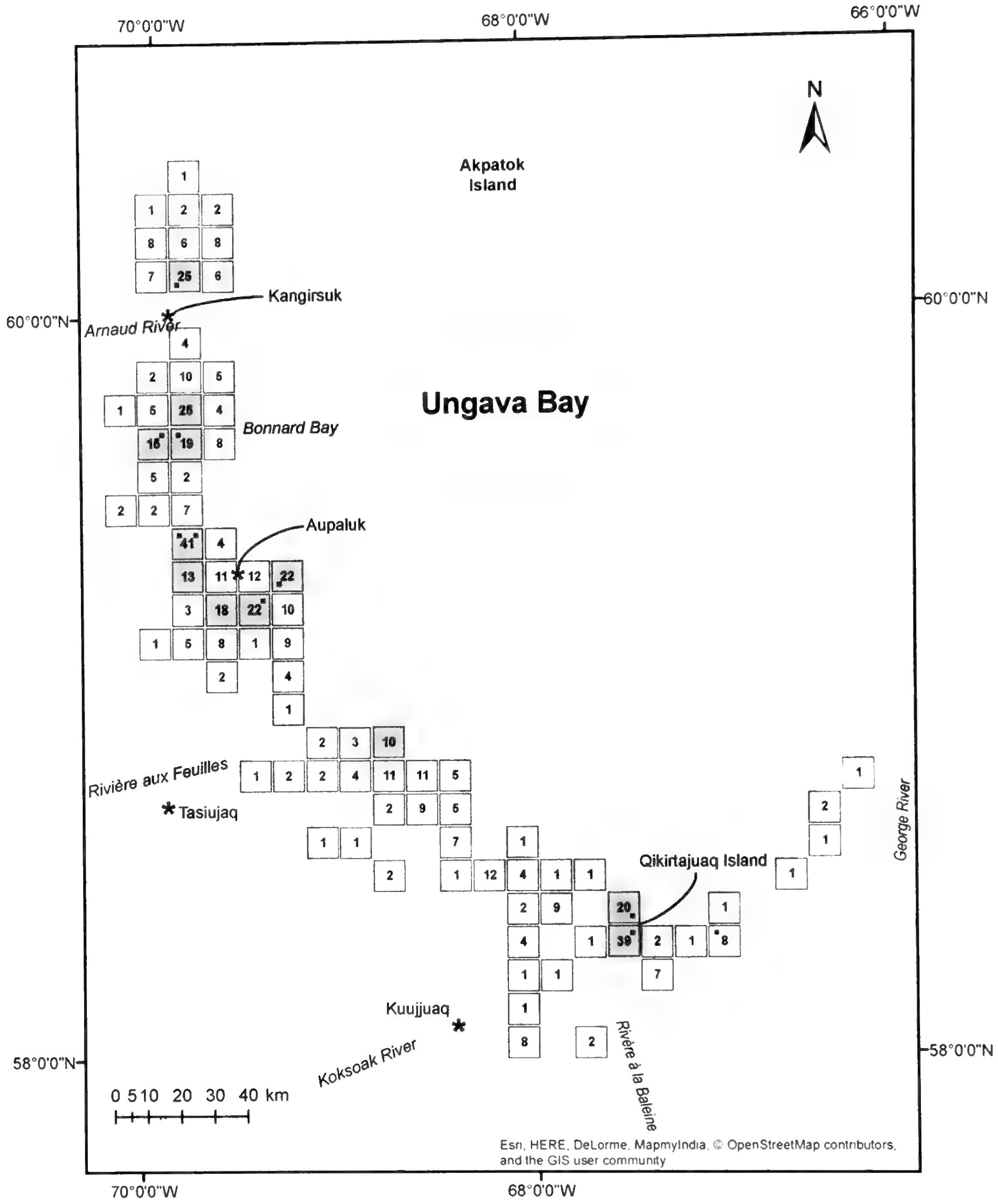

FIGURE 3. Map of Ungava Bay, northern Quebec, with distribution of 10 km × 10 km squares where Atlantic population Canada Geese (*Branta canadensis*) were captured and banded from 1997 to 2014. The number inside each square is the total number of catches made over the 18-year period. Squares in which geese were captured in nine or more years are shaded grey. Quadrants (25 km^2), within a square, in which geese were captured in seven or more years are indicated as small black square symbols.

To analyze the distribution of moulting and catch sites, for each year, I calculated the number of catches per 100 km^2 (i.e., 10 km × 10 km squares using a UTM grid system, the same system and square nomenclature used by Gauthier and Aubry (1996: 71) in the Quebec breeding bird atlas; a grid of survey squares in a Google Earth file is available online at the web site of the second Quebec atlas (http://www.atlas-oiseaux.qc.ca/googleearth_en.jsp). These squares were plotted on a topographic base map using ArcGIS 10.1 (ESRI, Redlands, California, USA) with the total (all years combined) number of catches per square.

To examine distribution and use at a larger scale, I divided each square into four 25-km^2 (5 km × 5 km) quadrants: southwest (sw), northwest (nw), northeast (ne), and southeast (se). For each square and its four quadrants, I calculated the number of years catches were made. As a measure of regular (i.e., consistent) use across years for Hudson Bay, I set a criterion of 12 years (representing two-thirds of the 18-year banding period) and 9 years (one-half of banding period) for squares and quadrants, respectively, while for Ungava Bay, I set the criterion at 9 years and 7 years for squares and quadrants, respectively.

The mean distance (km ± standard error [SE]) between capture locations was calculated for all recaptures combined, as well as for subgroups (example, Hudson Bay versus Ungava Bay), using the statistical software SAS (PROC MEANS, SAS Institute, Cary, North Carolina, USA). That is, for an individual recaptured goose, I calculated the distance between the site where it was recaptured and the site where it was originally captured and banded. A number of birds were recaptured in multiple years and, therefore, to control for non-independence, I used only the first recapture of each bird. For Hudson Bay and Ungava Bay, I tested for effects of sex, age at banding, and interval (number of years between initial capture and the recapture), and included year as a random variable, in a generalized linear mixed model (PROC GLM). The significance level was set at $a < 0.05$ for all tests.

Results

Distribution of brood-rearing and moulting sites

Between 1997 and 2014, 96 816 Canada Geese were captured and banded in 1917 catches. These catch sites were distributed over 175 100-km^2 squares along Hudson Bay ($n = 88$; Figure 2) and Ungava Bay ($n = 87$; Figure 3). Among all squares along Hudson Bay and Ungava Bay, 18 and 12 squares were used "regularly," respectively. For the two regions, the total number of catches (years combined) in these squares ranged from 24 to 144 and 10 to 41, respectively.

For Hudson Bay, however, the largest number of catches made in a single square would be 48 if the two squares (with 144 and 92 catches) encompassing the nesting study area (see Methods) were excluded. For Hudson Bay, all but one of the regularly used squares are located in a stretch of lowlands extending from the Mariet River in the south to just north of Shallow Bay. The exception is a square situated on the Sorehead River at the northern limit of the banding area (Figure 2). Sixty-one percent of all catches (816 of 1338) and 60% of total geese banded (34 419 of 56 891) along Hudson Bay were from these 18 squares, and, in all but one of these squares, the total number of geese captured and banded over the 18 years was > 1000. Fifteen of the squares had ≥ 1 quadrant (25 km^2) with catches in nine or more years (i.e., a regularly used quadrant) (Figure 2). The mean catch size along Hudson Bay was 42.5 geese (adults and goslings) (SE 0.68, $n = 1338$ catches); there was no difference in mean catch size between "regularly-used" and "non-regularly used" squares ($F = 0.39$, df = 1, $P = 0.53$).

Along Ungava Bay, 46% of all catches (269 of 579) and 50% of total geese banded (20 153 of 39 925) were from the 12 regularly used squares. The number of geese captured and banded over the 18 years was > 1000 in 10 of these squares. Geographically, 9 of these 12 squares are located north of Rivière aux Feuilles and are concentrated in three areas: Aupaluk, Lefroy River (which empties into Bonnard Bay), and Virgin Lake. The regularly used squares south of Rivière aux Feuilles are located at Ragged Point and Qikirtajuaq Island (encompassing two squares) (Figure 3). Eight of the 12 squares had ≥ 1 quadrants (25 km^2) with catches in seven or more years (Figure 3).

Both Ungava Bay and Hudson Bay had one regularly used quadrant within a non-regularly used square. On Qikirtajuaq Island, from 1997 to 1999 over 1000 geese were banded annually, but this declined to an average of less than 300 geese per year between 2000 and 2005, due primarily to nest predation by black bears. Since 2005, only two catches (each < 100 geese) have been made there, one each in 2008 and 2009.

The mean catch size along Ungava Bay was 69.0 geese (adults and goslings) (SE 1.42, $n = 579$ catches); the mean catch size in regularly used squares (74.9 ± 2.12, $n = 269$) was significantly larger than that in non-regularly used squares (63.8 ± 1.88, $n = 310$) ($F = 15.61$, df = 1, $P < 0.01$).

Dispersal distances and site faithfulness

From 1997 to 2013, 92 698 Canada Geese were captured and banded in Nunavik, of which 2828 (3.1%) different individuals were recaptured between 1998 and 2014. Whereas the majority were recaptured only once (91%, 2580 of 2828 geese), many were recaptured in more than one year: 202 geese in two years, 41 in three years, 4 in four years, and 1 in five years, resulting in a total of 3128 recaptures over the 17-year period. Among recaptures, the median interval between initial capture and first recapture was three years (range: 1–16 years). Of all recaptures, 28% (792 of 2828) were originally banded as goslings. Included in these recapture totals, but excluded in subsequent analyses, are two birds, both males and both originally captured as juveniles along Hudson Bay but recaptured as adults along Ungava Bay (individual distances of 415 km and 438 km). These were the only geese to have switched regions. Also excluded were recaptures of Canada Geese ($n = 209$) that were not originally banded in Nunavik as part of this current program. I obtained from the Bird Banding Office (Canadian Wildlife Service) original banding data for all Canada Goose recaptures from 2005 to 2014, and 98.6% (1456 of 1477 geese) were originally banded in Nunavik (including four Canada Geese banded in Nunavik before 1997 as part of an earlier banding program) and 1.4% from states or provinces in the Atlantic and Mississippi flyways.

For all birds and years combined, the mean and median distances between the first recapture site and original (banding) capture site were 4.3 km and 1.5 km, respectively (Table 1). Birds from Hudson Bay and Ungava Bay dispersed an average of 4.6 km and 3.8 km, respectively. Juveniles moved on average 5.4 km farther than adults, whereas males moved 1.4 km farther than females. The sex difference among juveniles was even greater, with males dispersing on average twice as far as females, 11.5 km versus 5.7 km (Table 1). For both Hudson Bay and Ungava Bay, the sex difference was not significant (Hudson Bay: $F = 2.51$, df = 1, $P = 0.11$; Ungava Bay: $F = 3.38$, df = 1, $P = 0.07$), but age at initial capture, the interval (number of years) between initial capture and first recapture, and year were all highly significant ($P < 0.01$). For Hudson Bay, all interactions among the four variables were significant ($P < 0.05$), whereas for Ungava Bay only the year–interval interaction was significant ($P < 0.01$).

Ninety-three percent (2630 of 2826) of all recaptures were within 10 km of their original banding location. Furthermore, nearly two-thirds (62%, 1754 of 2826) were within 2 km and one-third (33%, 943 of 2826) were within 1 km of their original banding location. The percentage of birds recaptured within 10 km of their original capture site was very similar between regions (Hudson Bay 92% versus Ungava Bay 94%) and sex (male 90% versus female 96%), but less similar between the two age groups (adult 97% versus juvenile 83%) (Figure 4). Among juveniles only, this percentage was lower for males (72%) than females (91%) (Figure 4).

TABLE 1. Descriptive statistics for the distances (km) between original capture site and first recapture site in a subsequent year for all Canada Geese (*Branta canadensis*) combined (All), Hudson Bay, Ungava Bay, females (F), males (M), adults (A), juveniles (J), and juvenile females (JF) and juvenile males (JM), in Nunavik, northern Quebec, 1998–2014.

Subgroup	*n*	Median	Mean	SE	CV	Min.	Max.	P10*	P90*
All	2826	1.476	4.269	0.220	0.273	0.017	187.775	0.437	6.437
Hudson	1577	1.487	4.607	0.303	0.261	0.039	130.431	0.423	7.197
Ungava	1249	1.467	3.842	0.317	0.291	0.017	187.775	0.450	5.963
F	1528	1.399	3.631	0.284	0.306	0.017	187.775	0.415	5.289
M	1298	1.635	5.021	0.341	0.244	0.020	178.736	0.468	9.926
A	2036	1.296	2.753	0.191	0.313	0.020	187.775	0.384	4.219
J	790	2.563	8.177	0.590	0.203	0.017	130.431	0.583	20.236
JF	454	1.885	5.738	0.688	0.256	0.017	130.431	0.474	9.131
JM	336	4.258	11.472	1.002	0.160	0.041	111.460	0.864	34.798

Note: SE = standard error, CV = coefficient of variation.
*10th and 90th percentiles (i.e., 80% of *n* falls within this range).

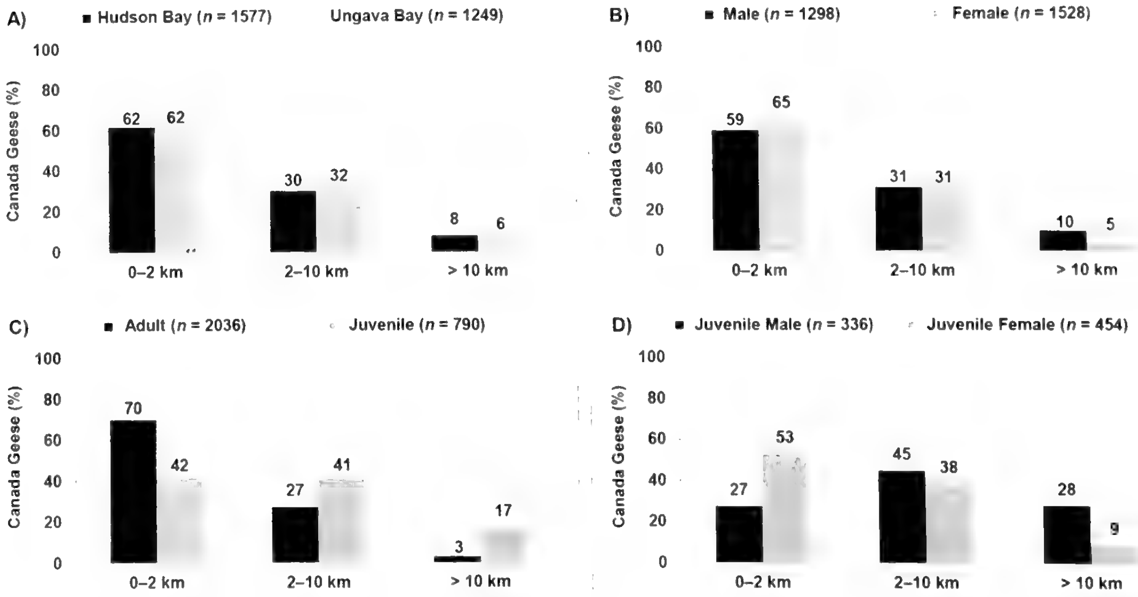

FIGURE 4. Percentage of Canada Geese (*Branta canadensis*) recaptured 0–2 km, 2–10 km, and > 10 km from original capture (banding) site, for four subgroups: A. Hudson Bay and Ungava Bay, B. Male and female birds, C. Birds first captured as adults versus juveniles, and D. Males and females first captured as juveniles. Sample size of each group is in parentheses.

Discussion

For Canada Geese nesting along eastern Hudson Bay, Nunavik, there are two important brood-rearing and moulting areas: a 90-km stretch of coastal lowlands extending north from the Mariet River to Shallow Bay (about 20 km southwest of Puvirnituq) and along the Sorehead River (about 60 km north of Puvirnituq), with both areas extending inland from the coast approximately 30 km. Along Hudson Bay, over half of all catches and birds banded were from the 17 squares used "regularly" located in the Mariet River–Shallow Bay area. Along Ungava Bay, since the mid-2000s, three areas have been used consistently for brood-rearing and moulting (i.e., encompassing regularly used squares) and all are located north of the Rivière aux Feuilles: Aupaluk (20-km radius around the community), Lefroy River, which empties into Bonnard Bay, and Virgin Lake. A fourth area is Qikirtajuaq Island, a large island located south of Rivière aux Feuilles. This island was a major nesting and banding site in the 1990s, but in the early 2000s nest predation by black bears increased dramatically and, as a consequence, the number of geese rearing broods and moulting there declined dramatically. As fewer and fewer geese were nesting and moulting south of Rivière aux Feuilles, banding effort in subsequent years was shifted to north of the river — the percentage of all catches from south of the river declined from 60% for 1997–2005 to 10% for 2006–2014. Because of this shift in banding effort from one area to another, for Ungava Bay a lower criterion for "regular" use for the 100-km^2 squares was used.

Pooling years and regions (Hudson Bay and Ungava Bay), 93% of recaptured geese moved $\leq$ 10 km from the site they were captured in an earlier year while 86% moved $\leq$ 5 km. This latter percentage is very similar to that for Brant (*Branta bernicla*) on Banks Island where Cotter and Hines (2006) reported 88% of recaptures occurred within 5 km of their previous site of capture. Because goslings are unable to fly until mid-August, broods cannot move long distances between nesting and brood-rearing areas. In their study of Atlantic population geese nesting in the vicinity of Tuksukatuk Camp on the Polemond River, Cotter *et al.* (2013) reported that goslings (web-tagged at time of hatching) traveled an average of 7.2 km (median = 4.0 km) from their nest to the site where they were captured at 4–6 weeks of age during the banding program. As geese show high fidelity to nesting areas (Cooke *et al.* 1975; Lindberg *et al.* 1995), this explains the commitment of Atlantic population Canada Geese to their brood-rearing–moulting locations. For both Hudson Bay and Ungava Bay, there was no significant difference in distances moved by male and female geese, although there was an age effect with juveniles dispersing farther than adults. Compared with female Canada Geese in this study, female Snow Geese (*Chen caerulescens*) nesting on Bylot Island (Nunavut) moved longer distances; Mainguy *et al.* (2006) reported an overall average of 25.6 km for Snow Geese but a considerable range (2.6–52.5 km) depending on the area selected by females to rear their brood.

In 2008, a management plan was produced for the Atlantic population of Canada Geese (Atlantic Flyway Council 2008). One of its objectives pertains to habitat management with a strategy to "monitor habitat conditions, potential development projects, and other threats to ensure protection of critical nesting and brood-rearing habitats." As a step toward this objective, this paper provides quantitative data on the distribution of brood-rearing–moulting sites as well as faithfulness to these sites.

Acknowledgements

Financial support for the banding program was provided by the Canadian Wildlife Service, the United States Fish and Wildlife Service, and the Atlantic Flyway Council. A large number of people with these three organizations, as well as Makivik Corporation (Nunavik Research Centre), participated in the banding program and their help is greatly appreciated. I thank the following people, who for several years gave up their time in August for banding: Ed Robinson, Francis St-Pierre, Guillaume Tremblay, Jack Hughes, Joël Poirier, Josée Lefebvre, Kevin Jacobs, Peter May, Sandy Suppa, Pierre Brousseau, Jim Bennett, Jean Rodrigue, Sébastien Paradis, Shirley Orichefsky, and Ted Nichols. Sincere thanks to Ted Nichols for also reviewing this manuscript. I thank the Canadian Coast Guard, Ontario Ministry of Natural Resources and Forestry, and Nunavik Rotors, in particular the helicopter pilots, for their friendship and professionalism in flying as well as for their assistance on the ground with banding operations. The support given to this project by the Nunavik Hunting, Fishing, and Trapping Association is greatly appreciated, as is as the considerable help given each year with logistics by Aliva Tulugak in Puvirnituq.

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Received 19 November 2014
Accepted 23 April 2015

Range Extensions for Northern Redbelly Dace (*Chrosomus eos*), Fathead Minnow (*Pimephales promelas*), and Iowa Darter (*Etheostoma exile*) in Ontario, Canada

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Goertz, Derek E., and R. Dean Phoenix. 2015. Range extensions for Northern Redbelly Dace (*Chrosomus eos*), Fathead Minnow (*Pimephales promelas*), and Iowa Darter (*Etheostoma exile*) in Ontario, Canada. Canadian Field-Naturalist 129(3): 237–244.

Relatively little is known of the distribution of small fish in the far north of Ontario, Canada, particularly in the Hudson Bay Lowlands. Between 2009 and 2014, we sampled 81 locations across six study areas in Ontario's far north to determine the extent of species occurrences beyond their reported ranges. We used galvanized minnow traps and a standardized effort as well as incidental sampling that included dip and seine netting. We documented 25 fish species across the region, including three species beyond their known geographic ranges: Northern Redbelly Dace (*Chrosomus eos*, Cyprinidae), Fathead Minnow (*Pimephales promelas*, Cyprinidae), and Iowa Darter (*Etheostoma exile*, Percidae).

Key Words: Northern Redbelly Dace; *Chrosomus eos*; Fathead Minnow; *Pimephales promelas*; Iowa Darter; *Etheostoma exile*; Hudson Bay Lowlands; range extension; Ontario

Introduction

Previous ichthyological sampling across Ontario's far north has focused primarily on the region's larger lakes or species of economic importance. Relatively little is known about the region's fish communities (Mandrak and Crossman 1992a; Browne 2007), especially those in its creeks, rivers, and small- to medium-sized lakes (Marshall and Jones 2011). Much of our knowledge comes from the earlier sampling efforts of Dymond and Scott (1941), Ryder *et al.* (1964), and the Ontario Ministry of Natural Resources' Aquatic Habitat Inventory (Zalewski and Weir 1981; Marshall and Jones 2011). In addition, during the summer of 2011 and 2012, the Ontario Ministry of Natural Resources and Forestry sampled the fish communities of 22 selected lakes (ranging in size from 298 ha to 63 000 ha) in fisheries management zones 1, 2, and 3, using both large- and small-mesh gill nets as described in the Manual of Instructions for Broad-scale Fish Community Monitoring (Sandstrom *et al.* 2013). The geographic boundaries of zones 1, 2, and 3 roughly correspond to those of Ontario's far north (Figures 1–3). The state of aquatic ecosystem knowledge in the far north has been summarized by Marshall and Jones (2011) and illustrates the lack of sampling effort in the Hudson Bay Lowlands beyond the larger lakes.

Climate change models and trends suggest that this region may undergo dramatic ecological change over the coming decades resulting from warmer temperatures and an increase in precipitation (FNSAP 2010). With current land use activities shifting from hunting, trapping, fishing, and resource-based tourism toward development, including large-scale mineral exploration, it is becoming increasingly important to improve our knowledge of the baseline biological condition to inform land use planning and resource management decisions more effectively and evaluate the associated effects on the region's biological resources.

From 2009 through 2014, we undertook small-fish sampling across Ontario's far north as a component of a larger study to investigate the biodiversity of this area in support of community-based land use planning. The specific objective of our small-fish sampling was to determine the extent of species occurrence beyond their reported ranges.

Study Area

The sampling took place across the Hudson Bay Lowlands and Ontario Shield ecozones within the boundaries of Ontario's far north as defined by Ontario's Far North Act, 2010, S.O. 2010, c.18 s.2.

The Hudson Bay Lowland is the third largest wetland in the world (Abraham and Keddy 2005) and covers approximately 25% of Ontario's land mass (Crins *et al.* 2009). This ecozone is dominated by saturated peatlands (Riley 2003) comprising open and treed bogs and fens over a very flat topography of underlying limestone. Lakes are generally shallow and rivers are typically low gradient. Together, lakes and rivers account for less than 3% of the region's surface area (Marshall and Jones 2011). Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) and Tamarack (*Larix laricina* (Du Roi) K. Koch) are the dominant tree species. Upland coniferous forests occur on well-drained sites along

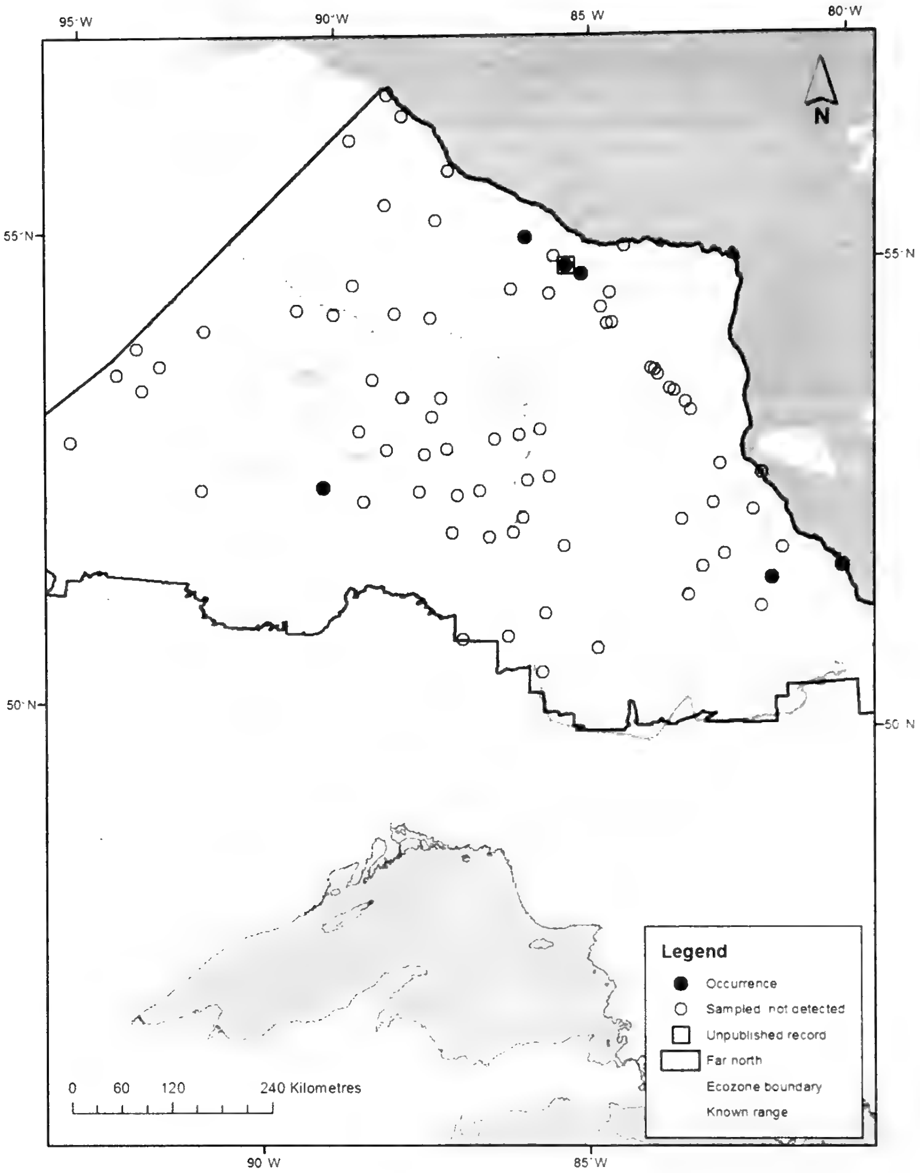

FIGURE 1. Distribution of Northern Redbelly Dace (*Chrosomus eos*) in northern Ontario. Previous known range (light gray) is according to Holm *et al.* (2009) and Eakins (2014). Square indicates unpublished record from the Royal Ontario Museum Ichthyology Collection.

river levees and old beach ridges (Riley 2003); marsh ecosystems predominate in supratidal areas along the coast (Glooschenko 1980); and, tundra heath occupies the northernmost portion of the ecozone adjacent to the Hudson Bay coast (Crins *et al.* 2009). Mean annual temperature ranges from −5.1 to 0.5°C, mean annual precipitation from 490 to 833 mm, and mean summer rainfall from 204 to 286 mm (Mackey *et al.* 1996a,b; Crins *et al.* 2009).

The project area also spans the northern portion of the Ontario Shield ecozone (ecoregions 2W and 3S), represented by underlying Precambrian bedrock, typically gneisses and granites. Land cover includes coniferous and mixed forest with wetlands and open water becoming more abundant in the north and east (ecoregion 2W), where it reaches more than 30% coverage (Crins *et al.* 2009). Black Spruce predominates the landscape, with Jack Pine (*Pinus banksiana* Lambert) becoming more common on upland sites to the south (ecoregion 3S). Lakes are widespread across the ecozone and vary in size, depth, and shoreline complexity, while high-gradient rivers occur occasionally (Marshall and Jones 2011). Lowlands are dominated by bogs and fens. Mean annual temperature ranges from −4.1 to 1.0°C, mean annual precipitation from 550 to 787 mm, and mean summer rainfall from 222 to 299 mm (Mackey *et al.* 1996a,b).

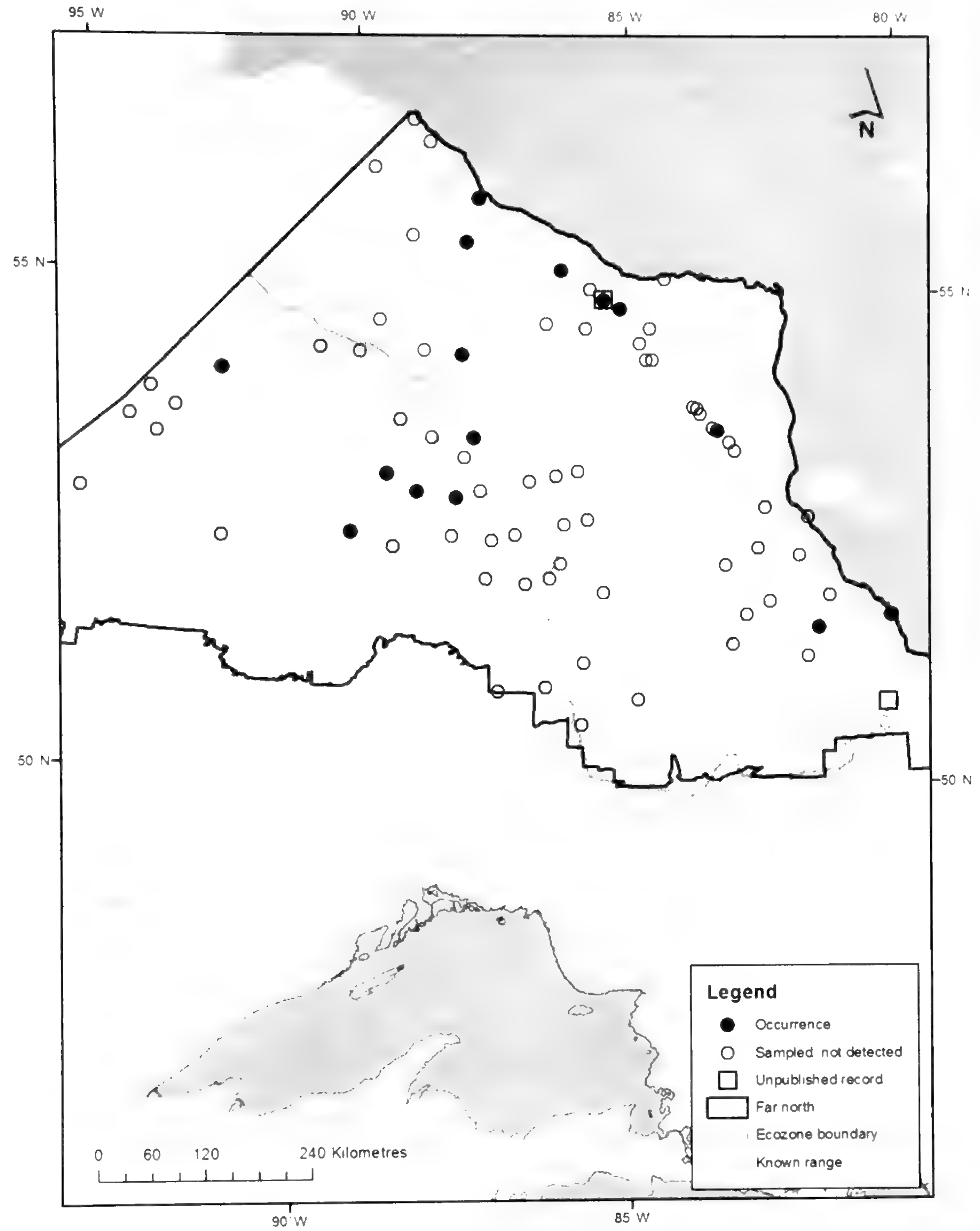

FIGURE 2. Distribution of Fathead Minnow (*Pimephales promelas*) in northern Ontario. Previous known range (light gray) is according to Holm *et al.* (2009) and Eakins (2014). Squares indicate unpublished records from the Royal Ontario Museum Ichthyology Collection.

Each year, study areas were selected based on existing information gaps, community land use planning status, and community interest, with the objective of achieving representative geographic and ecological coverage across the far north. One or two communities were selected each year as staging centres. A 150-km radius around each of these communities was used to delineate the outer limit of the study areas, based on the operational range of a fully loaded EC130 B4 helicopter (Airbus Helicopters Canada, Fort Erie, Ontario) used to shuttle field crews and gear to survey plots. In 2010, the study area was centred on a proposed large-scale chromite mining development known as the Ring of Fire, rather than on a single community. The greater distances to the nearest staging community necessitated a smaller study area than in other years. A 100-km study area radius was used to limit flight distances to 150 km from staging communities.

Over the six-year period (2009–2014), sampling was conducted during June and July with some sampling carried out in August of 2009 and 2014. Table 1 lists study areas, survey dates, and sampling effort.

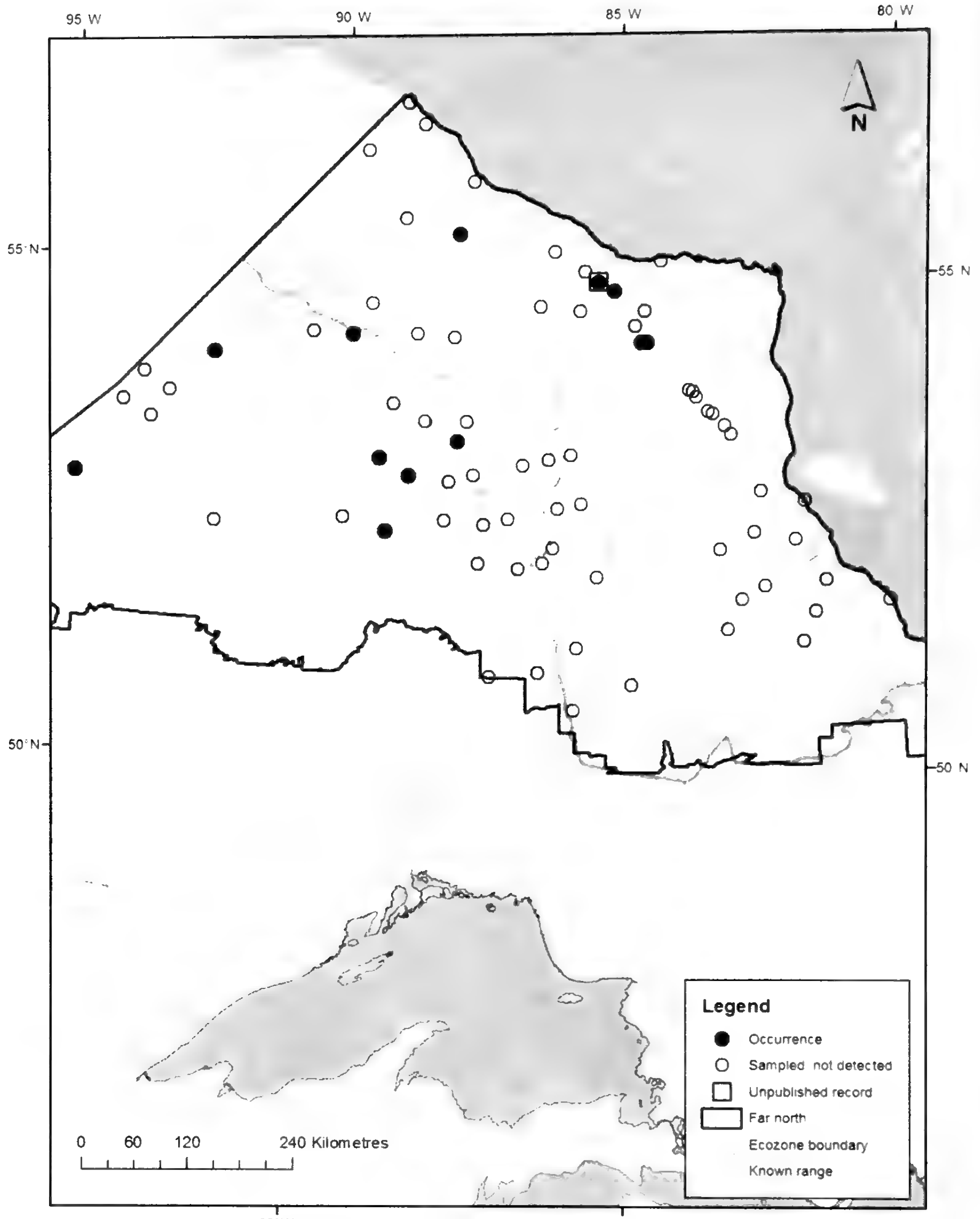

FIGURE 3. Distribution of Iowa Darter (*Etheostoma exile*) in northern Ontario. Previous known range (light gray) is according to Holm *et al.* (2009) and Eakins (2014). Square indicates unpublished record from the Royal Ontario Museum Ichthyology Collection.

TABLE 1. Study areas in northern Ontario, survey dates, and fish trapping effort from 2009 to 2014.

Study area	Coordinates	Survey dates	Effort (trap-nights)
Peawanuck	54.99760°N, 85.42729°W	6 June–15 August 2009	68
Ring of Fire	52.76884°N, 86.75541°W	3 June–22 July 2010	201
Kitchenuhmaykoosib Inninuwug	53.82391°N, 89.88082°W	2–21 June 2011	75
Keewaywin	53.00689°N, 92.79464°W	29 June–17 July 2011	64
Fort Albany	52.19999°N, 81.66670°W	5 June–14 July 2012	180
Nibinamik	52.74583°N, 88.51388°W	7–27 June 2013	88
Marten Falls	51.63566°N, 85.93040°W	2–22 July 2013	94
Fort Severn	55.99846°N, 87.61549°W	3 June–13 August 2014	239

Methods

Sample plots within the year's study areas were randomly selected from the National Forest Inventory 20 km × 20 km sampling grid (Gillis *et al.* 2005). Study areas typically spanned multiple ecodistricts and, as a result, plots were stratified across ecodistricts to ensure representative coverage. When selected plots were inaccessible due to unsuitable helicopter landing conditions (e.g., very wet or heavily forested sites), they were relocated to the nearest available landing area in similar habitat.

Four galvanized steel minnow traps (dimensions = 21 cm × 40 cm) were placed in aquatic environments in each plot to target small fishes. Trap locations were selected by field crews on arrival, based on the available habitat and an attempt to sample different aquatic habitats (preferably two lotic and two lentic). Traps were placed a minimum of 100 m apart and were completely submerged adjacent to cover (if available) to maximize the potential for captures.

Each trap was baited with a handful of dry dog food and a ball of crumpled tinfoil and checked at approximately 24-h intervals with an intended sampling effort of 16 trap-nights per plot; eight nights in 2009. All specimens were identified and counted each time traps were checked, and three voucher specimens per species (or presumed species) were kept and preserved in 70% denatured ethanol (denaturing agent: methanol). Up to six voucher specimens of a presumed species were collected at each trap location. Remaining captures (represented by vouchers) were released. Voucher specimens were identified according to Holm *et al.* (2009), Hubbs and Lagler (2004), and Scott and Crossman (1998). Nomenclature follows that of Page *et al.* (2013).

Although minnow trapping was the primary method used to capture small fishes, specimens were often collected incidentally through the use of dip nets and, in a few cases, non-standardized seine netting.

Data associated with species not presented in this paper can be obtained through the Ministry of Natural Resources and Forestry's Northeast Biodiversity and Monitoring Unit. Voucher specimens are curated at the Royal Ontario Museum.

Results

Of the 25 species encountered during this study (Table 2), three were beyond their known geographic range: Northern Redbelly Dace, Fathead Minnow, and Iowa Darter (Table 3). We hypothesize that these range extensions are an artifact of historical undersampling in the region and not a result of expansion into previously uninhabited areas during recent times. Examination of the postglacial dispersal history of Ontario's freshwater fishes supports our hypothesis; it suggests that these species recolonized this portion of Ontario via the same dispersal routes as other generally distributed species currently known from these areas (Mandrak and Crossman 1992b). All individuals of these species were found in habitats consistent with their preferred habitats as described in Holm *et al.* (2009). Northern Redbelly Dace and Iowa Darter are categorized as cool water species with thermal tolerance similar to that of known small fish communities of this area of Ontario (Eakins 2014). Fathead Minnow, although a warm water species (Eakins 2014), is similarly found in association with cool water species, such as Northern Pearl Dace (*Margariscus nachtriebi*) and Finescale Dace (*Chrosomus neogaeus*), both known from this region (Scott and Crossman 1998; Eakins 2014). Although our detection of the three species may have resulted from recent intentional or unintentional release and subsequent establishment, that is unlikely given the extremely remote and dispersed locations of much of our sampling.

TABLE 2. Fish species encountered in eight study areas in Ontario's far north during a 2009–2014 biodiversity study.

Scientific name	Common name
Chrosomus eos	Northern Redbelly Dace
Chrosomus neogaeus	Finescale Dace
Couesius plumbeus	Lake Chub
Notropis atherinoides	Emerald Shiner
Notropis heterolepis	Blacknose Shiner
Notropis hudsonius	Spottail Shiner
Pimephales promelas	Fathead Minnow
Rhinichthys cataractae	Longnose Dace
Margariscus nachtriebi	Northern Pearl Dace
Catostomus commersonii	White Sucker
Moxostoma macrolepidotum	Shorthead Redhorse
Salvelinus fontinalis	Brook Trout
Esox lucius	Northern Pike
Percopsis omiscomaycus	Trout-perch
Lota lota	Burbot
Culaea inconstans	Brook Stickleback
Gasterosteus aculeatus	Threespine Stickleback
Pungitius pungitius	Ninespine Stickleback
Cottus bairdi	Mottled Sculpin
Cottus cognatus	Slimy Sculpin
Etheostoma exile	Iowa Darter
Etheostoma nigrum	Johnny Darter
Perca flavescens	Yellow Perch
Percina caprodes	Logperch
Sander vitreus	Walleye

Discussion

Northern Redbelly Dace is a small slightly deep-bodied fish (Holm *et al.* 2009), averaging 5.1 cm total length (Scott and Crossman 1998). It is widely distributed in Ontario south of approximately 51°N where it inhabits cool, heavily vegetated, and often "tea-stained" waters of lakes and streams (Holm *et al.* 2009). Current distribution mapping indicates two records that constitute two disjunct ranges in the coastal areas adjacent to Hudson and James Bays (Holm *et al.* 2009; Eakins 2014). We captured 23 individuals across six plots located throughout the region. Five of these locations are beyond the current known geographic range of this

TABLE 3. Range extension records for three species collected in Ontario's far north during a 2009–2014 biodiversity study.

Species	Location of sampling station*	Number of individuals†	Collection date(s)	ROM catalogue number(s)‡
Chrosomus eos (Northern Redbelly Dace)	51.65170°N, 81.85013°W	8	14 June 2012	97683, 97779
	52.58490°N, 89.68137°W	1	8 June 2013	97828
	54.93470°N, 85.13696°W	8	29 July 2009	97782, 97787, 97790, 97793, 97799, 97806, 97809
	55.02319°N, 85.42319°W	1	4 June 2014	97767
	55.32119°N, 86.18961°W	2	2 July 2014	97733, 97744
Pimephales promelas (Fathead Minnow)	51.65170°N, 81.85013°W	33	14–16 June 2012	97681, 97682, 97778
	52.98093°N, 87.92592°W	2	7 June 2010	95901
	53.02609°N, 88.59720°W	160	17–20 June 2013	97865, 97867, 97870, 97873
	53.59674°N, 87.65428°W	11	25, 27 June 2013	97690, 97701, 97703, 97704,
	53.68443°N, 83.46362°W	1	7 June 2014	97698
	54.44064°N, 87.90157°W	148	20, 22 June 2014	97691, 97700, 97719, 97721, 97729, 97752, 97769, 97772, 97833
	54.93217°N, 85.13396°W	2	11 June 2009	97783, 97823
	55.02308°N, 85.42307°W	175	12 August 2014	97705
	55.32135°N, 86.18558°W	44	2, 4 July 2014	97670, 97724
	55.58220°N, 87.87726°W	712	25, 26 June 2014	97737, 97749, 97754, 97756, 97760, 97763, 97771, 97776
Etheostoma exile (Iowa Darter)	53.39635°N, 87.80255°W	2	24 June 2013	97875
	54.43194°N, 89.66885°W	2	4 June 2011	97711
	54.93470°N, 85.13696°W	10	11, 12 June, 29 July 2009	97797, 97805, 97813, 97818, 97824
	55.02319°N, 85.42319°W	4	4 June 2014	97742, 97768
	55.48249°N, 87.88128°W	2	25, 28 June 2014	97764, 97775

*Coordinates are given for a single sampling station within a plot where a record was obtained. In some cases, records were obtained from multiple stations.

†Total number of individuals captured from plot (sum of all station totals).

‡Royal Ontario Museum Ichthyology Collection catalogue numbers for all vouchers collected from a given plot.

species (Figure 1). Eighteen individuals (from one to eight per plot) were captured at these locations, which are 40–150 km (approximately) from the edge of this species' known range.

Fathead Minnow is a small deep-bodied fish, averaging 5.1 cm total length (Scott and Crossman 1998). It is widely distributed in Ontario south of the Hudson Bay Lowlands where it inhabits shallow lakes and streams (Holm *et al.* 2009). Current distribution mapping indicates five records that constitute four disjunct ranges in the coastal areas adjacent to James and Hudson Bays (Holm *et al.* 2009; Eakins 2014). We captured 3311 individuals across 15 plots located throughout the region. Ten of these locations are beyond the current known geographic range of this species (Figure 2). A total of 1288 individuals (one to 712 per plot) were captured at these locations, which are 10–150 km (approximately) from the edge of this species' known range.

Iowa Darter is a small elongate fish, averaging 5.1 cm total length (Scott and Crossman 1998). It is widely distributed in Ontario south of the Hudson Bay Lowlands where it inhabits clear waters of lakes and streams (Holm *et al.* 2009) with organic to sand substrates (Eakins 2014). Current distribution mapping indicates four records that constitute a disjunct range within the Hudson Bay Lowlands in the vicinity of the Sutton Ridges (Holm *et al.* 2009; Eakins 2014). We captured 97 individuals across 12 plots located throughout the region. Five of these locations occur beyond the current known geographic range of this species (Figure 3). In total, 20 individuals (two to ten per plot) were captured at these locations, which are 2–160 km (approximately) from the edge of this species' known range.

Databases associated with the Canadian Museum of Nature (2014), the Royal Ontario Museum (2014), and the Ontario Ministry of Natural Resources and Forestry's Broad-scale Fish Community Monitoring program (J. Amos, personal communication) were searched for unpublished records of each of these species. The Royal Ontario Museum Ichthyology Collection contains unpublished records for Northern Redbelly Dace (ROM 84983), Fathead Minnow (ROM 36391 and 84985), and Iowa Darter (ROM 84984) (Figures 1–3).

Given the remoteness of Ontario's far north and the logistic and financial challenges associated with accessing it, especially the interior, it is not surprising that there is a paucity of information about the region's fish communities, particularly its small-fish communities. As the far north receives more attention through planning and development initiatives, the need to establish baseline natural conditions and implement monitoring programs will be paramount. Increasing our knowledge of the region's biodiversity will undoubtedly lead to a finer resolution of the geographic distribution of many species, including small fish.

Acknowledgements

Funding for the Far North Biodiversity Project was provided by the Ontario Ministry of Natural Resources and Forestry's (MNRF) Far North Branch. The authors extend a special thanks to Jane Toppozini and Paul Sampson for making this project possible; to our steering committee, Ken Abraham, Bill Crins, Bob Watt, Dennis Donovan, Don Sutherland, and Dave Etheridge; and to the communities of Peawanuck, Marten Falls, Webequie, Nibinamik, Kitchenuhmaykoosib Inninuwug, Keewaywin, Fort Albany, and Fort Severn for their hospitality and support in working on their traditional lands.

Finally, we thank our field staff; MNRF aviation services for getting us to and from plots safely; Derek Farrer and Erling Holm for verifying fish identifications; the Royal Ontario Museum for curating our voucher specimens; Jeff Amos (MNRF) for providing information about MNRF's Broad-scale Fish Community Monitoring program; and Erling Holm, Nicholas Mandrak, Mike Oldham, and John Ringrose for thoughtful review of this manuscript.

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Received 2 March 2015
Accepted 22 July 2015

Behaviour and Nesting Ecology of Appalachian Ruffed Grouse (*Bonasa umbellus*)

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Smith, Brian W., Andrew N. Tri, Chris A. Dobony, John W. Edwards, and Petra Bohall Wood. 2015. Behaviour and nesting ecology of Appalachian Ruffed Grouse (*Bonasa umbellus*). Canadian Field-Naturalist 129(3): 245–253.

The substantial decline of Ruffed Grouse (*Bonasa umbellus*) in the southern Appalachian Mountains has been attributed in part to poor recruitment with possible links to nesting ecology. However, despite extensive research, the incubation ecology of Ruffed Grouse remains poorly understood. During 1999–2001 in West Virginia, we used videography of nesting female Ruffed Grouse to (1) quantify incubation constancy (minutes on the nest/minutes recorded) and nest survival during incubation, (2) determine whether incubation constancy predicts hatch success (proportion of eggs hatched per clutch), (3) determine the effect of the onset of laying on incubation constancy and hatch success, and (4) quantify nest visitors and depredation. Females spent about 96% of the recorded time incubating their clutches. Average incubation time per day increased by 1 h between day 1 and day 24 of incubation. Females generally left their nests twice daily, once in the morning between 0700 and 1000 for 31.7 ± 2.4 minutes (standard error) and again in the evening between 1600 and 1800 for 33.6 ± 1.5 minutes. Daily survival of nests (99.3 ± 0.4%) and nest survival for the incubation period (84.9 ± 9.3%) were high. Hatch success (the proportion of eggs that hatched among nests where at least one hatched) was high: 94.9 ± 0.02%. We found no relation between incubation constancy and hatch success. We recorded American Black Bear (*Ursus americanus*), Raccoon (*Procyon lotor*), and Long-tailed Weasel (*Mustela frenata*) as nest predators.

Key Words: Ruffed Grouse; *Bonasa umbellus*; infrared cameras; incubation ecology; incubation constancy; nesting behaviour; predation; hatch success; Appalachian Mountains; West Virginia

Introduction

Ruffed Grouse (*Bonasa umbellus*) populations are more abundant in southern Canada and the Great Lakes region where aspen (*Populus* spp.) stands predominate than in areas where aspen is a relatively minor forest component, such as the southern Appalachian Mountains (Norman *et al.* 2004). Moreover, grouse numbers in the southern portion of their range are declining faster than those of their northern counterparts, although the cause of the decline is unknown (Dessecker and McAuley 2001). Tirpak *et al.* (2006) suggest that the low productivity of grouse in the southern Appalachians may be reduced further by lower habitat quality. Relatively little information (Devers *et al.* 2007) exists concerning incubation behaviour of Ruffed Grouse and how that behaviour may influence nest success, depredation, or overall productivity. This information is critical to our understanding of grouse breeding ecology in a region that is different from the vast majority of Ruffed Grouse range and distribution.

Incubation behaviour in birds varies widely based on three main selection pressures: (1) the need to maintain a constant thermal environment suitable for embryo development, (2) the energy demands on the incubator, and (3) predation risks (Flint and Grand 1999). Many species of birds exhibit female-only incubation (White and Kinney 1974; Ehrlich *et al.* 1988), which influences reproductive effort and, thus, evolution of life-history traits for these species (Lack 1954; Williams 1966; Conway and Martin 2000a). Females must find a balance between maintaining egg temperature for proper embryo development and foraging to meet their energy demands during incubation (Williams 1996; Conway and Martin 2000b).

The frequency and duration of foraging bouts (leaving the clutch to feed) influence the amount of energy needed to rewarm eggs (Vleck 1981; Williams 1996), whereas the hunger level of a female often determines the length of time she incubates eggs before leaving to forage (Kendeigh 1952; White and Kinney 1974; Weathers and Sullivan 1989). In addition, risk of nest predation can influence incubation behaviour as females reduce activity at or near nests to avoid attracting predators (Prescott 1964; Martin 1996; Martin and Ghalambor 1999). Optimizing foraging time may also reduce the number of egg-exposure days by maximizing the rate of embryonic development (Ricklefs 1969; Bosque and Bosque 1995; Conway and Martin 2000b), thereby decreasing the overall duration of incubation. For these reasons, incubation and associated behaviours may directly influence reproductive success.

Ruffed Grouse is a ground-nesting species with female-only incubation, relatively large clutches (range 9–14 eggs), brief off-nest periods (recesses), and precocial young (Bump *et al.* 1947; Maxson 1989). Incubation takes 23–24 days and females may not re-lay if they lose their first clutch (Haulton 1999; Rusch *et al.* 2000).

Videography has proved to be a valuable tool for determining incubation behaviour and identifying nest predators for a variety of galliforms (Marini and Melo 1998; Rader *et al.* 2007; Coates and Delehanty 2008; Coates *et al.* 2008). We used videography to better understand Ruffed Grouse incubation ecology in the Southern Appalachians. Our objectives were to: (1) quantify incubation constancy (minutes spent on the nest/minutes recorded) and nest survival through incubation, (2) determine whether incubation constancy predicts hatch success (proportion of eggs hatched per clutch), (3) determine the effect of the onset of laying on incubation constancy and hatch success, and (4) quantify nest visitors and depredation. We made the following predictions based on our knowledge and published findings. (1) Incubation constancy would be similar throughout the incubation period. Maxson (1977) found no significant increase or decrease in incubation time for females, except for the last two days during which hatching began. (2) Hatch success would be positively related to incubation constancy because females that left the nest less frequently would maintain more consistent egg temperature. (3) Females that laid clutches earlier would have higher incubation constancy because ambient temperatures are colder in early spring and more energy is required to maintain clutch temperature. (4) *Peromyscus* spp., *Tamias striatus*, *Procyon lotor*, and *Mephitis mephitis* would constitute the majority of nest visitors and/or nest predators (Bump *et al.* 1947; Henry 1969; Dobony *et al.* 2001).

Study Area

We conducted our research in the MeadWestvaco Wildlife and Ecosystem Research Forest (MWERF) near Adolph (38°42'N, 80°3'W) in Randolph County, West Virginia, as part of the Appalachian Cooperative Grouse Research Project. The MWERF, a 3413-ha second-growth forest, was established in 1994 to examine the impacts of modern and intensive forest management on ecological processes in the Appalachian region.

Elevations in the MWERF range from 740–1200 m, and climate is moist and cool with average rainfall and snowfall of 114 cm and 150 cm, respectively (Fenneman 1938; Strausbaugh and Core 1977). Soils are acidic and typically well drained (Stephenson 1993). Forest cover is Allegheny hardwood–northern hardwood at higher elevations and cove-hardwood and mixed mesophytic forest at lower elevations (Eyre 1980). The Allegheny hardwood–northern hardwood forest type is dominated primarily by Yellow Birch (*Betula alleghaniensis* Britton), American Beech (*Fagus grandifolia* Ehrhart), Sugar Maple (*Acer saccharinum* L.), Red Maple (*A. rubrum* L.), Black Cherry (*Prunus serotina* Ehrhart), Red Spruce (*Picea rubens* Sargent), White Ash (*Fraxinus americana* L.), and Fraser's Magnolia (*Magnolia fraseri* Walter). Lower elevation species include Yellow-poplar (*Liriodendron tulipifera* L.), Sweet Birch (*B. lenta* L.), Northern Red Oak (*Quercus rubra* L.), and American Basswood (*Tilia americana* L.) (Ford and Rodrigue 2001). Riparian areas of the MWERF are a mixture of Red Spruce, Eastern Hemlock (*Tsuga canadensis* (L.)), and Rosebay Rhododendron (*Rhododendron maximum* L.). The shrub layer throughout the forest consists of Rosebay Rhododendron and Striped Maple (*A. pensylvanicum* L.).

Methods

Trapping

From 1998 to 2000, we trapped female Ruffed Grouse in the MWERF during the fall. We resumed trapping in early spring (March to mid-April) to replace female grouse that had died or whose radio had failed during winter months. We captured grouse using modified lily-pad traps (Gullion 1965) with 10- to 16-m leads that consisted of 46-cm-high poultry wire to guide grouse into the traps. Leads ran between two trap bodies (i.e., one trap at each end).

On capture, all grouse were weighed, aged as adults or juveniles based on primary shape and moult pattern (Kalla and Dimmick 1995), and banded with number 12 butt-end aluminum leg bands (National Band and Tag, Newport, Kentucky, USA). Females were fitted with a necklace-type radio transmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA). Transmitters weighed 10–11 g, had mortality sensors, and were equipped with two-year batteries. All trapping and handling procedures were approved by the West Virginia University Animal Care and Use Committee (protocol 01-0405).

Nest searching and monitoring

We located females three times a week beginning 1 March and ending with the start of incubation during 1999–2001. Using a two-element Yagi antenna and a telemetry receiver (Wildlife Materials, Model TRX-2000S, Carbondale, Illinois, USA), we obtained a minimum of three azimuths from permanently located telemetry stations and determined female locations via triangulation (Mech 1983). We plotted azimuths on topographic maps. To determine onset of egg laying and incubation, we monitored females' activity and movement, both of which tend to decrease once egg laying commences (Maxson 1977, 1978; Johnsgard 1983). We located nests by homing in on telemetry signals (Mech 1983) and visually observing incubating females.

Camera installation

We installed Fuhrman Microcam2 miniature video cameras (Fuhrman Diversified, Inc., Seabrook, Texas, USA) over grouse nests (three in 1999, 11 in 2000, and seven in 2001). We installed cameras immediately after locating each nest, as long as the nest contained five or more eggs; if a nest contained fewer than five eggs, we delayed installing a camera until after the fifth egg was laid. To reduce disturbance at nest sites, we mounted only the camera (enclosed in a camouflaged aluminum housing) approximately 0.5–0.7 m over the nest. Cameras were connected by a 20-m coaxial cable to time-lapse video cassette recorders (VCRs) and deep-cycle 12-volt marine batteries. We ran cables under logs and shrubs to camouflage their presence, and the VCRs were placed in waterproof black cases that were tucked under shrubs and camouflaged with natural items (e.g., sticks and leaves). We wore rubber gloves and boots to reduce our scent when installing the cameras and when changing VCR tapes. We visited the VCRs daily to change recording tapes (standard T-160 videocassettes) and batteries.

Cameras emitted infrared light (950 nm wavelength) that was not visible to vertebrates (Aidley 1971). In darkness, the infrared emitters were capable of illuminating objects up to one metre from the camera. The camera and infrared emitters were enclosed in a 32 mm × 32 mm × 60 mm aluminum housing and attached to an articulating arm. Recording units recorded four black-and-white images per second (one-third the speed of standard VCR) continuously for 24 h (Williams and Wood 2002). After camera installation, no birds were flushed from their nests during visits to change batteries and videocassettes (assessed visually and via video).

During 2001, we removed three of the seven cameras shortly after installation to avoid researcher-induced nest abandonment (i.e., females appeared cautious or agitated by camera presence as evidenced by erect crest and entering the nest and immediately departing). Over the course of the study, cameras were active at 10 nests during the egg-laying period and 18 early in the incubation period.

Video transcription

We transcribed female behaviour captured on videotape beginning at midnight on the day of camera installation; the time lag from camera installation to midnight appeared sufficient to allow females to accept the camera and resume normal behaviour. From the video footage, we determined: (1) duration of egg-laying visits; (2) onset of incubation; (3) amount of time spent incubating and during recess bouts; and (4) identity of nest visitors. We considered that incubation began when the female remained on her nest overnight. We also used video footage to determine exact times and dates for all hatching events, barring battery/camera failure. Video setups (camera, recorder, and battery) were designed to record for 24 h; however, due to equipment failure (battery failure, camera or videotape malfunction) and nest depredation, the actual amount of footage transcribed varied by tape (range 4–24 h) and nest (range 104–797 h).

We assigned video transcription data to two categories based on when we started monitoring nests: laying period and incubation period. One female's nesting attempts (WV348, captured first when she was an adult) were recorded in both 2000 and 2001, but we considered them independent because attempts occurred in separate years and nests were in different locations within her home range. We excluded from analyses the first day of incubation or first day of videotape for each bird to reduce bias caused by nest disturbance.

Statistical analyses

We completed all statistical tests on camera data using R 3.0.0 (R Foundation for Statistical Computing, Vienna, Austria). We considered differences or effects statistically significant at $\alpha = 0.10$. We calculated incubation constancy (minutes incubating/total minutes recorded per day) to standardize incubation time among birds and tape time because of equipment failure. We pooled years (1999–2001) and age classes (adults and juveniles) because of the small number of nests in our sample. We calculated hatch success as the proportion of eggs that hatched among nests where at least one egg hatched. We assessed daily survival rates of nests (probability of a grouse nest surviving one day) and nest survival (probability of a grouse nest surviving until hatch) using the Nest Survival platform (Dinsmore *et al.* 2002) in Program MARK 7.0 (White and Burnham 1999). Because of our small sample size, we fit no grouping variables or individual covariates. The constant survival model (daily survival rate is constant) in MARK is a maximum likelihood estimate that is an extension of Mayfield's (1961) estimator (Johnson 1979; Dinsmore *et al.* 2002).

We used generalized linear mixed models to assess relations between nesting behaviours and hatch success, and how those behaviours changed throughout the incubation cycle. The random factor in all linear models was each individual bird, because of lack of independence of measurements on the same individual over the course of nesting. To determine whether incubation constancy was a function of how long a female had been incubating the clutch, we constructed a generalized linear mixed model using the "lme4" library with day in the incubation cycle (1–24) as the fixed variable, individual bird as the random explanatory variable, and incubation constancy as the response variable. We also generated linear mixed models to determine (1) how incubation constancy influenced hatch success, (2) how onset of incubation influenced incubation constancy, and (3) how onset of incubation influenced hatch success. We estimated a pseudo r^2 using the Nakagawa and Schielzeth (2013) method for each generalized linear mixed model to determine how much variation in the data was explained.

Results

After removing cameras where birds were disturbed, we videotaped three nests during 1999, 11 nests during 2000, and four nests during 2001. Average date of onset of incubation was 29 April ± 1.9 days (standard error; range 23 April–9 May). Average clutch size was 10.6 ± 0.6 eggs/clutch (range 9–13, n = 18 clutches). Daily survival of nests was 99.3 ± 0.4%. Probability of a nest surviving the duration of incubation (nest survival) was 84.9 ± 9.3%.

Egg-laying behaviour

We monitored 10 females via video cameras during the egg-laying stage. Overall, females laid 4.5 ± 0.7 eggs (range 2–7) after camera placement, averaged 10.6 ± 0.5 eggs per clutch (range 9–13, n = 10 clutches), and averaged 209 ± 20 minutes on the nest per egg-laying event (range 58–537 minutes). Following egg deposition, all females attempted to cover their nests with leaf litter. They would also place one to several leaves on their back and/or tail while sitting in the nest bowl, and then slowly walk away from the nest, allowing the leaves to slide off their back onto the nest and eggs. None of the nests in our sample was depredated during egg laying.

Incubation behaviour

We monitored 18 females for a total of 311 incubation-days and recorded an average clutch size of 10.9 ± 0.4 eggs (range 9–12). Four nests were depredated during this period. Hatch success (proportion of eggs hatched per clutch) was 74.6 ± 10.9% for all females, but improved to 94.9 ± 0.02% when we excluded depredated clutches. On average, incubation constancy was 95.5 ± 0.4% (average incubation time was 22.7 ± 0.1 h/day). There was a weak relation (r^2 = 0.22, t_{279} = 5.37, P < 0.001) between incubation constancy and day of the nesting cycle. From day 1 to day 24 of incubation, average incubation time per day increased by 61.3 ± 12.2 minutes (Figure 1). Females generally left their nest twice daily, once in the morning between 0700 and 1000 for 31.7 ± 2.4 minutes and again in late afternoon between 1600 and 1800 for 33.6 ± 1.5 minutes (Figure 1).

We found no relation between incubation constancy and hatch success (t_{309} = 0.50, P = 0.627) or between onset of incubation and incubation constancy (t_{309} = −1.24, P = 0.217). Our results indicated that incubation constancy is not a good predictor of hatch success.

Nest visitors

During the egg-laying period in 2000, we detected four nest visitors (from three different taxa) at three nests (Table 1), but we recorded no depredation attempts. All visitors (i.e., a mouse, *Peromyscus* sp., several salamanders, *Plethodon* spp., and an Eastern Chipmunk, *Tamias striatus*) entered nest bowls while females were absent from their nests, but did not damage or remove any eggs. We observed no other visitors during the egg-laying stage in any year.

During incubation, we detected one nest visitor (a weasel, *Mustela* sp.) during 1999, four nest visitors (four species and two taxa) at four nests during 2000, and six visitors (one species) at two nests in 2001 (Table 1). We visually observed one additional nest visitor, a

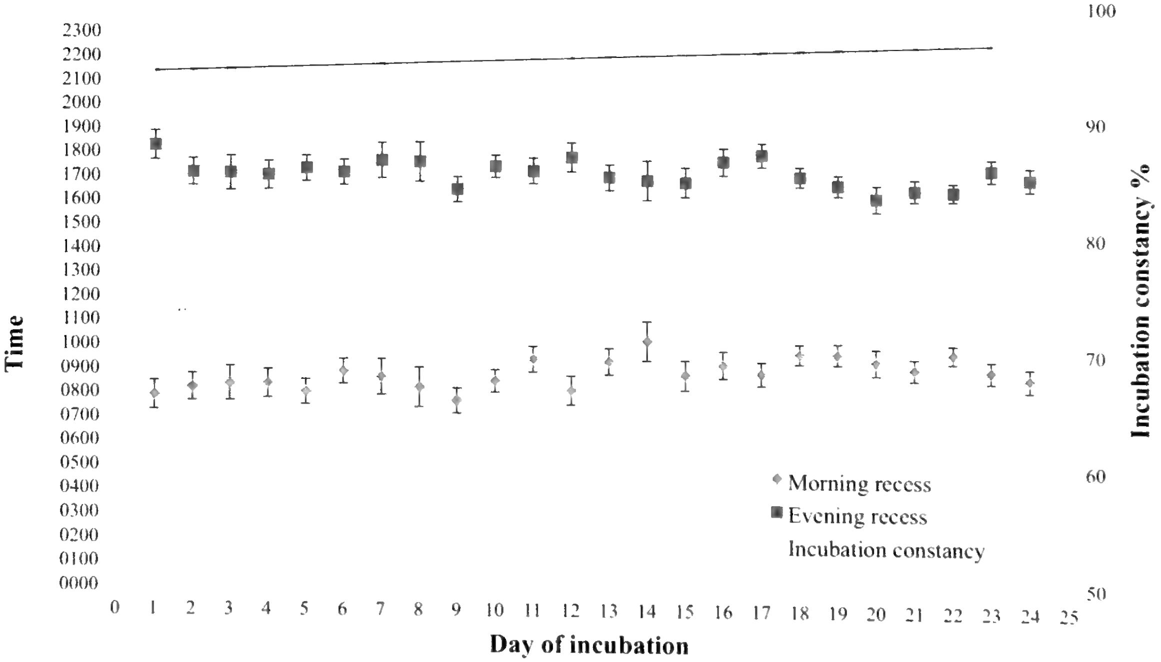

FIGURE 1. Incubation constancy (time on nest as % of recorded time) and recess times (mean ± standard error) for Ruffed Grouse (*Bonasa umbellus*) in the MeadWestvaco Ecosystem Research Forest in Randolph County, West Virginia, 1999–2001.

Raccoon (*Procyon lotor*), in 2000 while changing the battery and videotape in the VCR. The battery had failed overnight and we did not record the nest depredation event. A weasel (*Mustela* sp.) entered the nest of one female during 1999, but did not depredate any eggs. Eastern Chipmunks visited two nests in 2001, but no eggs were removed from either nest despite repeated visits (*n* 5) at one.

Video cameras recorded depredation events at three nests. A Long-tailed Weasel (*Mustela frenata*), an American Black Bear (*Ursus americanus*), and a Raccoon (*Procyon lotor*) consumed the entire contents of three nests during 2000. We also observed a shrew (*Sorex* sp.) near a nest removing all the shells of hatched eggs from the nest bowl. We are unsure whether the shrew consumed the eggshells or hid them nearby, because we were unable to locate them when we searched the area. Anecdotally, we observed a similar situation at another nest where hatching had recently (< 6 h) occurred; 10 of 11 eggs had hatched, and five shells of the hatched eggs had been pulled under a log about 0.5 m away. This behaviour of shrews (or other small mammals) could influence how researchers assess nest fates or nest predators, as finding no eggs (or nestling remains for songbirds) is usually considered indicative of snake or bird depredation (Hardy 1951; Best and Stauffer 1980; Hernandez *et al.* 1997; Williams and Wood 2002).

TABLE 1. Nest visitors and depredation events recorded during egg laying and incubation at Ruffed Grouse (*Bonasa umbellus*) nests in the MeadWestvaco Ecosystem Research Forest in Randolph County, West Virginia, 1999 2001.

Egg-laying stage					Incubation stage				
Bird ID	Date, m/d	Visitor	Duration, min:s	Outcome	Bird ID	Date, m/d	Visitor	Duration, min:s	Outcome
1999									
					WV305	5/2	*Mustela* sp.	00:47	No eggs harmed
2000									
WV144		*Peromyscus* sp.	00:02	No eggs harmed	WV175	5/2	*Plethodon* sp.	26:22	No eggs harmed
WV144	4/30	*Peromyscus* sp.	00:30	No eggs harmed	WV306	5/7	*Ursus americanus*	07:51	Female alive, eggs consumed
WV144	5/1	*Plethodon* sp.	06:57	No eggs harmed	WV313	5/6	*Procyon lotor*	01:34*	Female alive, eggs consumed
WV195	4/21	*Plethodon* sp.	20:50	No eggs harmed	WV347	5/16	*Mustela frenata*	13:36	Female alive, eggs consumed†
2001									
WV362	4/29	*Tamias striatus*	00:31	No eggs harmed	WV362	4/29	*Tamias striatus*	00:31	No eggs harmed
					WV362	5/4	*Tamias striatus*	00:13	No eggs harmed
					WV362	5/8	*Tamias striatus*	00:05	No eggs harmed
					WV362	5/15	*Tamias striatus*	00:05	No eggs harmed
					WV362	5/19	*Tamias striatus*	00:03	No eggs harmed
					WV380	5/14	*Tamias striatus*	00:03	No eggs harmed

*Raccoon (*Procyon lotor*) returned 52 min. later to search the nest bowl again and check all eggshell fragments for additional contents; it remained in view for 41 s.

†Long-tailed Weasel (*Mustela frenata*) returned to nest the following evening and removed eggs that B. W. S. had replaced (see Smith *et al.* 2003 for details); weasel was in view for 8 min. 54 s.

Discussion

We recorded incubation constancy of about 96% among successful females, which is similar to that found by Maxson (1977) in Minnesota. High rates of incubation constancy (i.e., > 90%) are common in the order Galliformes (e.g., Williams *et al.* 1971; McCourt *et al.* 1973; Naylor *et al.* 1988; Eaton 1992; Zwickel 1992; Schroeder *et al.* 1999; Coates and Delehanty 2008). We also found a weak, positive relation between incubation constancy and day of the nesting cycle; average incubation time per day increased by about 1 h/day over the period of incubation. Increased constancy in the last few days of incubation has also been noted in Greater Snow Geese (*Chen caerulescens atlanticus*; Reed *et al.* 1995) and Emperor Geese (*Chen canagica*; Thomson and Raveling 1987). Increased incubation constancy may result from increased communication between embryos and females (Reed *et al.* 1995; Rusch *et al.* 2000) or lower tolerance of embryos to sustained and substantial drops in temperature as they develop (MacMullan and Eberhardt 1953; Batt and Cornwell 1972). Cooper and Voss (2013) reported that the rate of heat loss from eggs increased with embryo age in Black-capped Chickadee (*Poecile atricapillus*). Female chickadees responded to the increase in cooling rates by altering their incubation constancy and corresponding recess bouts.

In our study, female Ruffed Grouse initiated egg laying and incubation at dates typical for the region

(Haulton 1999; Devers *et al.* 2007). Clutch size and hatch success reported here were also similar to the range found by Haulton (1999), Tirpak *et al.* (2006), and Devers *et al.* (2007). The female reproductive parameters in our study were representative of Ruffed Grouse in the central and southern Appalachian Mountains.

We found no support for our predictions that hatch success would be positively related to incubation constancy or that early layers would have higher incubation constancy. Female grouse were able to maintain high levels of constancy throughout incubation, which may enhance the likelihood of nest survival.

Diurnal recesses (about 30 minute duration) generally occurred in a bimodal distribution, with females leaving the nest once in the morning and again in late afternoon; no recesses occurred at night. Limiting the number of recesses may reduce the energy cost of incubation by reducing the number of times females must rewarm the clutch (Drent 1970; Gabrielsen and Unander 1987; Williams 1996). Energy demands and the depletion of nutrient reserves in the incubating female may also influence recess patterns. Coates and Delehanty (2008) observed decreased constancy in juvenile Greater Sage-grouse (*Centrocercus urophasianus*) during the later days of incubation and hypothesized that this may have been related to greater diminishing of body reserves compared with adults, which did not display this pattern. We were unable to test for differences in recess patterns between adult and juvenile grouse because of our small sample of juveniles (25%). The grouse we observed remained on their nests for 12–14 h throughout the nocturnal period. The need to forage to replenish their crops likely influenced the maximum duration of incubation (Wiebe and Martin 1997; Coates and Delehanty 2008). Leaving the nest during the day would be more efficient as higher daytime ambient temperatures would decrease the rate of heat loss by eggs during the female's absence.

Long recesses can slow embryo development if egg temperatures drop below a certain threshold (Haftorn 1988); thus, leaving the nest less frequently maximizes the rate of embryonic development, thereby reducing the number of days needed to hatch eggs and during which eggs are exposed to predators (Cody 1966; Ricklefs 1969; Bosque and Bosque 1995). Conway and Martin (2000a) found that nest predation appears to influence passerine incubation by constraining activity at the nest; passerine species that nest in substrates with high nest predation have evolved behaviour to minimize parental activity at the nest (i.e., mainly increased incubation constancy).

We recorded no nest depredation events during egg laying, potentially because activity at and around the nest is much less at this time than during incubation (Maxson 1977), thereby reducing visual or olfactory cues that predators might use to locate nests (Skutch 1949; Conway and Martin 2000a). However, female activity or olfactory cues at or near nests has the potential to attract both predatory and non-predatory species, possibly affecting nest success. The few depredation incidents we recorded are likely better explained by exposure time, rather than activity around the nest. Visitors during the egg-laying period (i.e., a mouse and several salamanders) did not attempt to remove or consume eggs. In addition, female Ruffed Grouse attempt to conceal their nests on departure from an egg-laying visit (B. W. S. and C. A. D., personal observations), a behaviour similar to that reported in female Wild Turkeys (*Meleagris gallopavo*; Healy 1992). This additional camouflage during the egg-laying period reduces egg visibility and likely reduces predator efficiency. However, once continuous incubation starts, female Ruffed Grouse do not conceal their nests when they depart, which is also similar to behaviour observed in Wild Turkeys (Williams *et al.* 1971).

Nest visitors during the incubation period included both predatory and non-predatory species. Eastern Chipmunks, commonly known to prey on eggs (e.g., Sloan *et al.* 1998), were observed at Ruffed Grouse nests on numerous occasions but never damaged or consumed eggs. Grouse eggs may be too large for chipmunks to open or remove from the nest bowl, but they may visit the nest repeatedly to check for damaged or partly hatched eggs. Mammalian predators destroyed 4 of 18 (22%) nests monitored during our study. This level of depredation was within the range observed throughout the Ruffed Grouse range (16–41%; Bump *et al.* 1947; Johnsgard and Maxson 1989; Rusch 1989; Haulton 1999; Dobony *et al.* 2001; Larson *et al.* 2001). Depredation was also within documented ranges of other grouse species (16–67%; Boag *et al.* 1984; Ritchie *et al.* 1994; Grisham *et al.* 2014). Both raccoons and weasels are common predators on Ruffed Grouse eggs in the Appalachian Mountains (Bump *et al.* 1947; Rusch *et al.* 2000; Dobony *et al.* 2001; Smith *et al.* 2003). American Black Bears are not known as common nest predators of Ruffed Grouse, but were found to depredate nests of Ruffed Grouse in our study. American Black Bears have been noted as predators of songbirds (Williams and Wood 2002) and artificial nests (Sloan *et al.* 1998).

Selection has shaped incubation behaviour in Ruffed Grouse to optimize productivity, maintain energy reserves, and reduce risk of predation. If predators locate nests or incubating females by observing activity around a nest, then females that enter and leave their nest less often will have an advantage in terms of lower risk of predation (Conway and Martin 2000a). Ruffed Grouse nests are usually located against or under an object (Bump *et al.* 1947; Johnsgard and Maxson 1989; Fettinger 2002), providing overhead cover and often perimeter cover from one or more directions. Moreover, most nests have a high percentage of vertical cover immediately surrounding nest sites (Thompson *et al.* 1987; Larson *et al.* 2001; Fettinger 2002), which may provide added protection from avian predators (Gullion 1972).

Acknowledgements

This study was conducted as part of the Appalachian Cooperative Grouse Research Project and was supported in part by the West Virginia Division of Natural Resources (Pittman-Robertson Federal Aid in Wildlife Restoration Project W–48–R) and the Division of Forestry and Natural Resources, West Virginia University. We thank the Richard King Mellon Foundation and the Ruffed Grouse Society for additional funding, MeadWestvaco Corporation for logistical support, and the West Virginia Cooperative Fish and Wildlife Research Unit for use of their video surveillance systems. In addition, we thank T. Allen, T. Olexa, R. Smith, and S. Sutton for assistance with fieldwork, Gary Norman for project guidance, Dr. George Seidel for statistical support, and Drs. Jim Belthoff and Barry Grand for reviewing early versions of our manuscript. The use of trade names or products does not constitute endorsement by the United States government.

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Received 11 July 2014
Accepted 7 June 2015

Are American Pikas (*Ochotona princeps*) in the Canadian Rockies Vulnerable to Climate Change?

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Shank, Christopher C. 2015. Are American Pikas (*Ochotona princeps*) in the Canadian Rockies vulnerable to climate change? Canadian Field-Naturalist 129(3): 254–262.

The American Pika (*Ochotona princeps*) is vulnerable to climate change as a result of its dependence on cool, moist conditions. Most research on climatic determinants of American Pika distribution has been done in the United States where conditions are different from those in the higher-latitude pika ranges of the Canadian Rockies. I examined recent (1980–2009) and future (2050s and 2080s) average and maximum mean summer temperatures for 114 current American Pika locations in Alberta to assess whether future conditions are likely to place these animals at risk. At all current sites, mean summer temperatures (MSTs) in the 2050s are expected to be below that chosen by the United States Fish and Wildlife Service as a threshold for at-risk status of *O. princeps*. By the 2050s, most current American Pika locations have sufficient elevation within 5 km to allow individuals to migrate vertically to reach habitat with MST similar to that of their current location. Even in the 2080s, almost all current sites have sufficient elevation within 5 km to maintain extreme single-year and average MSTs lower than the highest values recorded at those sites in the recent past (13.9°C and 12.5°C respectively). However, by the 2080s under an extreme greenhouse gas emissions scenario, only 34% of current pika sites will allow for such migration. Although considerable uncertainty remains, particularly with respect to availability of habitat, these results suggest that American Pika populations in Alberta will likely be capable of persisting throughout this century, although their survival will depend increasingly on successful vertical migration.

Key Words: American Pika; *Ochotona princeps;* Alberta; climate change; vulnerability; vertical migration; Rocky Mountains

Introduction

The American Pika (*Ochotona princeps*) has been variously described as a "poster child" (Hannibal 2012), "candidate indicator species" (Beever and Smith 2013), "sentinel species" (Wilkening *et al.* 2013, 2015), and "harbinger" (Smith *et al.* 2004) for the effects of climate change on biodiversity. Concerns over the effects of climate change on pikas arise from several sources including observations of population disappearance (Beever *et al.* 2003, 2011; Stewart *et al.* 2015), elevational retreat (Beever *et al.* 2003, 2011; Grayson 2005; Millar and Westfall 2010), susceptibility to acute (MacArthur and Wang 1974; Smith 1974a) and chronic heat stress (Beever *et al.* 2010; Wilkening *et al.* 2011; Stewart *et al.* 2015), increasing frequency of low precipitation and snowpack (Erb *et al.* 2011; Beever *et al.* 2013; Jeffress *et al.* 2013), limited dispersal ability (Seppänen *et al.* 2012; Beever and Smith 2013), restriction to areas of permafrost (Hafner 1993, 1994; Millar and Westfall 2010; Wilkening *et al.* 2015), dependence on higher elevations (Rodhouse *et al.* 2010), and habitat change (COSEWIC 2011).

As a result of such research, the United States Fish and Wildlife Service (USFWS) was petitioned to list the American Pika under the Endangered Species Act, but concluded that it is currently not endangered or threatened in the United States (USFWS 2010), a decision that some consider to be politically motivated (Holtcamp 2010). Although the American Pika has not been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), in 2011, the closely related but the allopatric Collared Pika (*Ochotona collaris*) of the Yukon, Northwest Territories, and Alaska was assessed as "special concern" by COSEWIC based largely on the potential for negative impacts of climate change, particularly reduction in suitable alpine habitat and increase in distance between habitat patches (COSEWIC 2011).

Most research on the American Pika's adaptations to climate change has been done in the United States; Canadian studies are limited to MacArthur and Wang (1973, 1974), Henry *et al.* (2012a,b), and Henry and Russello (2013). The Canadian Rockies can generally be characterized as having more contiguous high-elevation areas, cooler temperatures, longer winters, and more persistent snowpacks than in the United States.

It is largely accepted that, given suitable habitat and adequate forage, American Pika distribution is primarily determined by climatic factors, although there is no consensus on the particular factors. Recent efforts to establish a climatic envelope have used extensive data sets and sophisticated statistical techniques (Erb *et al.* 2011; Calkins *et al.* 2012; Ray *et al.* 2012; Jeffress *et al.* 2013; Erb *et al.* 2014; Stewart *et al.* 2015), but a clear understanding of the factors limiting pika distribution remains elusive. Suggestions from one or more authors have included elevation, aspect, mean annual temperature, acute heat stress, acute cold stress, chronic heat stress, precipitation, and snowpack. Non-climatic factors, such as talus type, amount of suitable talus upslope of current sites, habitat connectivity, vegetation abundance, and grazing, may play a role but are generally less predictive of pika persistence. Idiosyncrasies in climate conditions at the location of some pika populations have been noted (Simpson 2009; Jeffress *et al.* 2013).

Beever *et al.* (2010, 2013), Wilkening *et al.* (2011), and Stewart *et al.* (2015) found that chronic heat stress, determined by measuring mean summer temperature (MST) during June, July, and August, is the single best indication of whether an American Pika population will persist. The USFWS established an ambient MST of 16.2°C as their primary criterion for determining whether pika populations in the United States are at risk (USFWS 2010). This threshold was derived by subtracting one standard error from the observed mean summer sub-talus temperatures at which pikas were observed to disappear in the Great Basin (Beever *et al.* 2010). Pikas thermoregulate behaviourally by taking cover in rock crevices, suggesting that sub-talus temperature, rather than ambient temperature, is an important climatic factor to pika distribution. Sub-talus temperatures tend to be lower than ambient temperatures during the afternoon, but higher during the remainder of the day (Henry *et al.* 2012b), implying that mean ambient temperature is a reasonable approximation for mean sub-talus temperature.

This paper is intended to examine in detail whether summer temperatures at current American Pika locations in Alberta's Rocky Mountains are likely to remain below the level deemed to put pikas at risk and whether these pikas have sufficient vertical relief nearby to find suitable conditions by migrating up slope.

Methods

I accessed American Pika locations from the Bow Valley Naturalists' High Elevation Localized Species (HELS) project (Bow Valley Naturalists 2010) database. HELS is a citizen science project in which members of the public submit observations of American Pikas, White-tailed Ptarmigan (*Lagopus leucura*), Mountain Goats (*Oreamnos americanus*), and Hoary Marmots (*Marmota caligata*). Participants enter locations into the database by providing a Universal Transverse Mercator (UTM) reference or, more commonly, by clicking a point on an online map. Consequently, locations are more accurate than many museum records, in which rough coordinates are assigned to verbal location descriptions. Because most observations are made opportunistically, they reflect areas most traveled, i.e., near trails and roads. I filtered all 615 pika sites recorded in the HELS database between August 2010 and July 2014 to remove any locations outside Alberta and to ensure sample independence by removing all observations less than 3 km from another observation point. The 3 km independence limit was chosen to avoid duplicating sites resulting from inaccurate location recording, as well as reflecting dispersal distances (e.g., Meridith 2002). A total of 106 HELS locations met these criteria.

I included only two points from the extensive Global Biodiversity Information Facility (GBIF) website (GBIF n.d.). Most GBIF sites were not selected because they were within 3 km of an already chosen site; the coordinates were apparently estimated from general, verbal descriptions; or site examination using Google Earth suggested that it was unlikely pika habitat. Location data cited in Weimann *et al.* (2014) provided six additional sites for southwestern Alberta, separated by 3 km or more. Locations of the 114 sites are shown in Figure 1.

Elevation for each of the 114 locations and the highest points within 1, 2, 3, 4, and 5 km of each site were determined from a digital elevation model (Natural Resources Canada, n.d.) using Geospatial Modelling Environment v.0.7.0.2 tools (Hawthorne L. Beyer) and R v.2.15.2 (The R Foundation, Vienna, Austria). Site data are summarized in Table 1.

I employed ClimateWNA version 4.62 (Wang *et al.* 2012) to approximate historical and projected temperature variables. Historical temperatures were from 1980–2009. Future temperatures, for the 2050s (2041–2070) and the 2080s (2071–2100), were projected using an average of 23 global circulation models from Phase 3 of the World Climate Research Programme's Coupled Model Intercomparison Project (CMIP3). Although Phase 3 projections have been superseded by Phase 5, the two suites of models produce similar projections (Knutti and Sedláček 2013). The range of uncertainty regarding future climate was addressed by employing lower (B1) and higher (A1B) greenhouse gas (GHG) emission scenarios. The A1B storyline assumes rapid economic growth, a human population peaking in mid-century, and a subsequent decline and rapid introduction of new sources and technologies entailing a balance across all sources. The B1 scenario follows the A1B storyline but puts more emphasis on global solutions to economic, social, and environmental sustainability resulting in lower levels of GHG emissions (Murdock and Spittlehouse 2011).

First, I sought to determine whether average MST in the 2050s and 2080s at current American Pika sites in Alberta would exceed the USFWS threshold of 16.2°C.

Second, because American Pikas in the United States may be better adapted to warm conditions than in Alberta and, therefore, have a higher threshold temperature for persistence, I determined the proportion of the 114 current locations that would exceed the average MST of the warmest site in Alberta between 1980 and 2009. The highest average MST at the 114 sites was 12.5°C, a value that can be used as a provisional threshold MST specific for the American Pika in Alberta.

Third, I reasoned that exposure to a single summer with a very high MST might lead to sudden population extinction. Using ClimateWNA, I determined that the maximum single-year MST at any Alberta site, in the years 1980–2009, was 13.9°C and used this value as an Alberta-specific threshold for maximum single-year

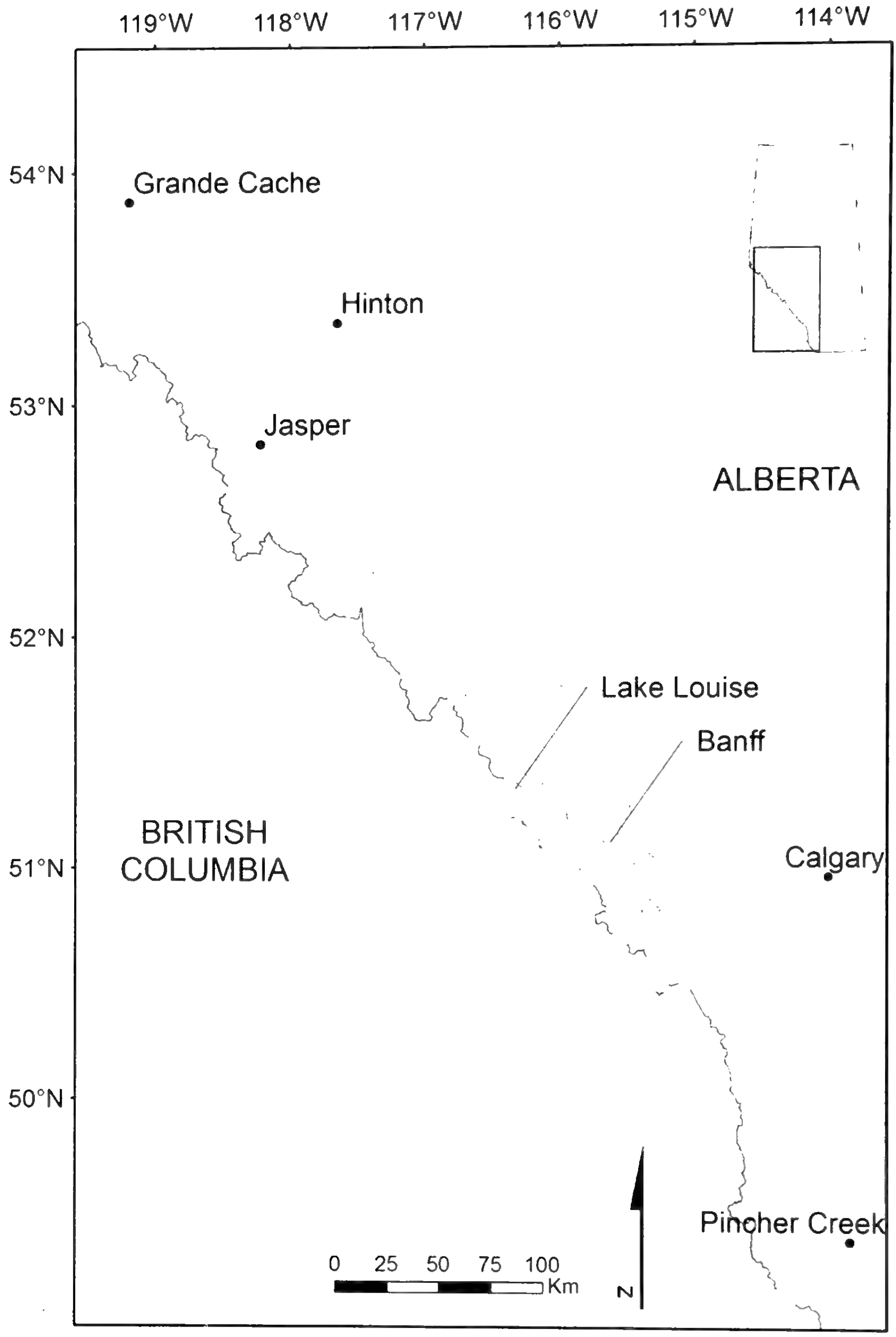

FIGURE 1. Locations of 114 reported American Pika (*Ochotona princeps*) observations used in the analysis (open circles).

TABLE 1. Summary of site data for the 114 American Pika (*Ochotona princeps*) locations in the Rocky Mountains, Alberta, used in this study.

	Maximum	Minimum	Median	Mean
Latitude	54.1	49.2	51.2	51.3
Longitude	-114.1	-119.4	-115.8	-115.9
Site elevation (m)	2647.8	1421.0	2196.8	2111.5
Highest elevation (m) with 1 km	3065.8	1440.0	2595.6	2504.6
Highest elevation (m) with 2 km	3458.3	1535.5	2796.8	2744.7
Highest elevation (m) with 3 km	3487.3	1990.5	2894.0	2849.7
Highest elevation (m) with 4 km	3487.3	2056.8	2969.8	2923.3
Highest elevation (m) with 5 km	3487.3	2083.0	3031.5	2969.9
Lapse rate (°C/1000 m)	-4.2	-5.3	-4.6	-4.6

MST. Because ClimateWNA does not calculate values for individual future years or provide estimates of between-year variance, I estimated the highest future single-year MST by adding, for each site, the difference between the highest single-year MST for the period 1980–2009 and the average MST for the same period.

The remaining two approaches I employed were to project whether pikas in Alberta would be able to maintain the three threshold MSTs (16.2°C, 12.5°C, 13.9°C) by moving to higher elevations. The question is whether the mountains near current pika locations are high enough in elevation to provide temperatures less than or equal to those experienced at current pika locations, the warmest average Alberta MST of 12.5°C or the maximum single-year MST of 13.9°C. I used lapse rates to predict the elevation at which the threshold MST would occur. Lapse rates are a measure of temperature change with elevation and are a linear function of elevation, but they differ with location, season, and climate variables. For each of the 114 pika locations, I calculated lapse rate for MSTs directly from ClimateWNA outputs by regressing MST on elevation. Values varied from −4.214°C to −5.313°C per 1000 vertical metres (Table 1). Wang *et al.* (2012) describe in detail how lapse rates were developed for Climate WNA. Ray *et al.* (2010) discuss some of the assumptions and sources of error in estimating lapse rates, and Wang *et al.* (2012) note that this approach does not capture temperature effects produced by small-scale topographic effects (e.g., aspect, slope, and frost pockets). Using the calculated lapse rates, I determined the elevation required to meet the threshold MST according to the following formula:

$$E_f = ((T_f - T_t) \cdot L^{-1}) + E_c$$

where E_f = elevation (m) in the 2050s and 2080s required to meet the threshold MST, T_f = future MST (°C) at the current location, T_t = the threshold MST (°C), L = the lapse rate (Δ°C per m of elevation gain), and E_c = the elevation (m) of the current site. The criterion for population persistence was E_f less than the elevation of the highest point within a distance over which pikas are capable of dispersing.

American Pikas are philopatric (Smith and Ivins 1983) and have traditionally been considered to be very poor dispersers (Galbreath *et al.* 2009). Earlier estimates of pika dispersal distances range from 100 m (Smith and Weston 1990) to 300 m (Smith 1974a), but depend on marked animals, a technique that generally results in shorter estimates than those using later genetic approaches (Peacock 1997). More recent studies indicate a wide range of dispersal distances including < 20 km (Hafner 1993), ≥ 2 km (Zgurski and Hik 2012), 2–10 km (Peacock 1997), and 3 km (Merideth 2002). Topographic complexity, water barriers, and west-facing slopes were the major factors found to restrict pika dispersal in Oregon (Castillo *et al.* 2014). Given the uncertainty in how far any particular pika population is likely to disperse, I chose to examine the highest elevations within 1, 2, 3, 4, and 5 km of current sites.

Results

Over the period 1980–2009, the average or maximum MST of 16.2°C that theoretically limits pika persistence in the United States was not exceeded at any of the Alberta sites (Figures 2 and 3).

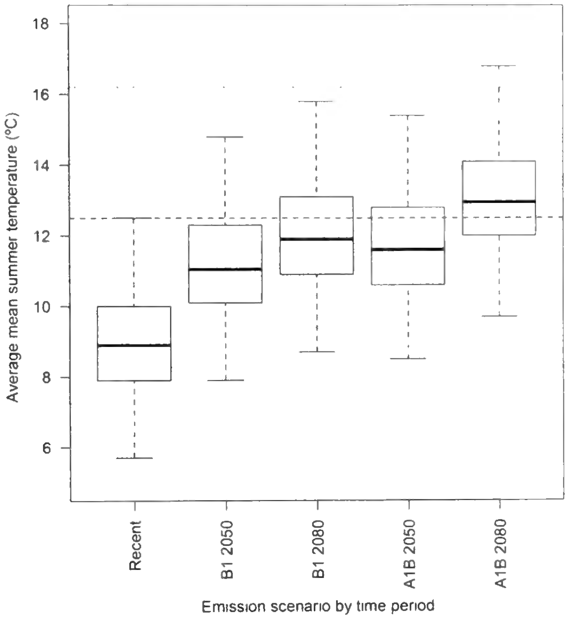

FIGURE 2. Mean summer temperatures (MSTs) averaged over the period 1980–2009 and projected average MSTs in 2050s and 2080s for lower (B1) and higher (A1B) greenhouse gas emission scenarios at 114 American Pika (*Ochotona princeps*) sites in Alberta. The horizontal dashed line represents the highest average MST (12.5°C) in 1980–2009 at these pika sites; the horizontal dotted line is the United States Fish and Wildlife Service risk threshold (16.2°C). The bottom and top of the boxes indicate the first and third quartiles, respectively, and the heavy horizontal bar the median. The whiskers represent extreme values.

Based on the USFWS criterion for persistence (average MST ≤ 16.2°C), none of the observed American Pika populations in Alberta is likely to be at risk from increased MST in the 2050s and in the 2080s under the B1 emission scenario (Figure 2). However, in the 2080s under the more extreme A1B emission scenario, the average MST is expected to exceed the threshold of 16.2°C at four sites (3.5%).

If one considers that a single-year with a maximum MST > 16.2°C might cause extinction of American Pika populations, then pikas at six (5.2%) of the current sites are in danger of extirpation in the 2050s under the more extreme A1B emission scenario, although

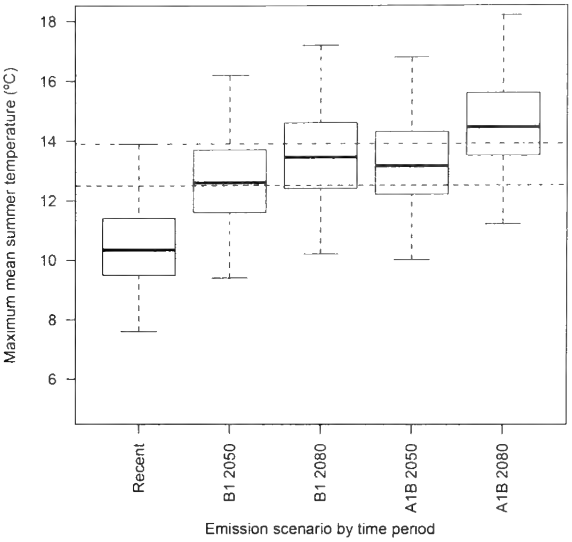

FIGURE 3. Maximum single-year mean summer temperatures (MSTs) for 1980–2009 and projected future (2050s and 2080s) extreme single-year MSTs for lower (B1) and higher (A1B) emission scenarios at 114 American Pika (*Ochotona princeps*) sites in Alberta. The horizontal dashed line represents the highest MST (12.5°C) in 1980–2009 at these sites, the horizontal dotted line is the United States Fish and Wildlife Service risk threshold (16.2°C), and the broken dashed line the highest single-year MST recorded for any site during 1980–2009. The bottom and top of the boxes indicate the first and third quartiles, respectively, and the heavy horizontal bar the median. The whiskers represent extreme values.

none are in danger under the B1 scenario. In the 2080s, four (3.5%) and 18 (15.8%) of the sites will exceed 16.2°C under the B1 and A1B scenarios, respectively (Figure 3).

Because temperatures are projected to rise throughout the range of the American Pika in Alberta, pikas will have to migrate up slope to remain at the MST of their current sites. The dispersal potential of pikas influences their ability to access suitable habitat at higher elevations. In the 2050s under the B1 emission scenario, sufficient elevation is available within 1 km of current sites to maintain historical average MSTs for 34.2% of sites and for 91.2% of sites within 5 km (Figure 4).

However, in the 2080s and under the A1B scenario, there are no sites with sufficient elevation within 1 km to maintain current average MSTs and only 34.2% of current sites have sufficient elevation with 5 km to do so (Figure 4).

Nevertheless, American Pikas at most current Alberta locations will continue to experience average MSTs less than 12.5°C, that of the warmest current Alberta site (Figure 5, dispersal distance = 0 km). With vertical migration, nearly all pikas will be able to find locations with MSTs < 12.5°C within 5 km (Figure 5, dispersal distance = 5 km).

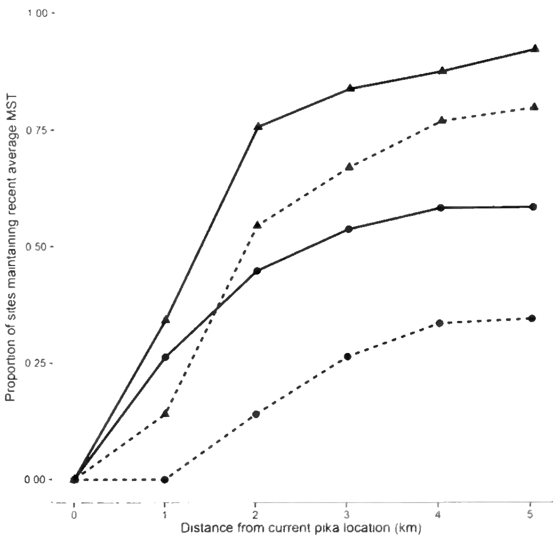

FIGURE 4. The proportion of 114 American Pika (*Ochotona princeps*) sites in Alberta where average mean summer temperatures are expected to remain less than or equal to those experienced between 1980 and 2009 at the current location (0 m) and at higher elevations within 1–5 km. The solid lines are the projections for the 2050s and the dotted lines for the 2080s. The lower emission scenario (B1) is indicated by circles and the higher emission scenario (A1B) by triangles.

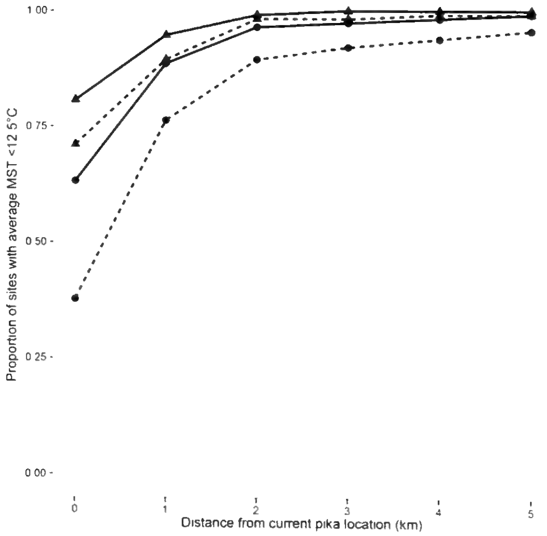

Figure 5. The proportion of 114 American Pika (*Ochotona princeps*) sites in Alberta where average mean summer temperature (MST) is expected to remain ≤ 12.5°C (i.e., the highest average MST for any site between 1980 and 2009) at the current location (0 m) and at higher elevations within 1–5 km. The solid lines are the projections for the 2050s and the dotted lines for the 2080s. The lower emission scenario (B1) is indicated by circles and the higher emission scenario (A1B) by triangles.

If a single year with an MST greater than the highest single-year MST of 13.9°C causes population extinction, then pikas at most current sites are likely to persist into the 2050s under both emission scenarios and into the 2080s under the B1 scenario (Figure 6, distance = 0 km). By migrating up slope within 5 km, almost all current pika populations will avoid extreme MSTs higher than those experienced by any Alberta population during 1980–2009 Figure 6, distance = 5 km) even under the more extreme A1B scenario.

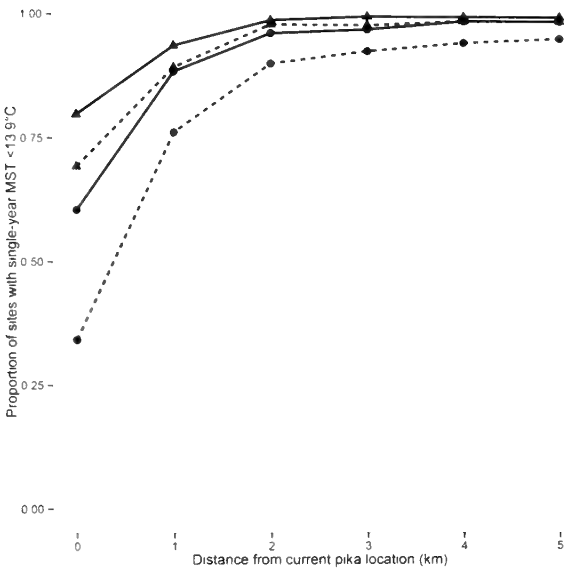

FIGURE 6. Proportion of the 114 American Pika (*Ochotona princeps*) locations in Alberta where single-year mean summer temperature (MST) is expected to remain ≤ 13.9°C (i.e., the highest single-year MST for any site in 1980–2009) at the current location (0 m) and at higher elevations within 1–5 km. The solid lines are the projections for the 2050s and the dotted lines for the 2080s. The lower emission scenario (B1) is indicated by circles and the higher emission scenario (A1B) by triangles.

Discussion

Based on analysis of MST alone, one can project that most current American Pika populations in Alberta will persist into the 2050s and, if GHG emissions are controlled, into the 2080s. Under the more extreme A1B emission scenario, most lower-elevation sites are likely to be abandoned by the 2080s. Up-slope migration will become increasingly important toward the end of the century, particularly if GHGs are not vigorously controlled. However, a changing climate may affect Alberta pika populations in manners not captured by analysis of MST alone.

Because of the fragmented nature of talus habitat, American Pikas exhibit classic metapopulation dynamics (Hanski 1998), in which regional populations may remain stable while local groups may disappear and their sites become recolonized. Consequently, pikas have been the subject of numerous empirical and theoretical metapopulation explorations (e.g., Peacock and Smith 1997). Climate change is likely to affect the quality of habitat patches, distance between suitable patches, and population demographics. Therefore, the balance between population extinction and recolonization may be altered in unpredictable ways.

This analysis addresses only the proximal effects of extreme and average MSTs on American Pika populations and does not consider the effects of climate change on habitat. In the Canadian Rockies, as elsewhere, talus slopes are the most common pika habitat and are usually formed by debris eroding from steep bedrock faces and collecting at the cliff foot where slope angle eases (Bithell *et al.* 2014). There is likely to be less such talus habitat at higher elevations where suitable temperatures may exist in the future.

American Pikas also require suitable vegetation within close proximity of talus fields. Vegetation can be expected to move up slope rapidly with warming temperatures (Schneider 2013). This is likely to result in loss of some meadow habitat through introgression of trees and shrubs and the creation of new meadow habitat at now-barren higher elevations, if soil conditions allow. Loss and addition of suitable habitat are likely to alter pika metapopulation dynamics in unpredictable ways. Climate-induced habitat loss was the major consideration in listing the Collared Pika as "special concern" in Canada (COSEWIC 2011).

Of particular uncertainty is the role of snow and cold in determining the distribution of American Pikas. Jeffress *et al.* (2013) speak of a "Goldilocks effect," whereby pikas in the western United States are squeezed between hot conditions at low elevations and cold, wet conditions at high elevations. My analysis addressed only the former situation. Snow blanketing the talus acts to insulate pikas from extreme cold. Beever *et al.* (2010) found below-talus temperatures to be colder in the absence of snow, and acute cold stress (defined as number of days with below-talus temperatures less than −5°C) to be among the better predictors of pika persistence in the Great Basin. Morrison and Hik (2007, 2010) reported the collapse of a population of Collared Pikas in the Yukon by 90% between 1998 and 2003, a period with later spring snowmelt associated with negative Pacific Decadal Oscillation values. Unfortunately, no suitable snowpack data exist that would allow for examination of these relationships for American Pika in Alberta.

American Pikas might also adapt to a warmer future climate. In a study of a population at the northern edge of the species range in west-central British Columbia, Henry *et al.* (2012a) concluded that there is less genetic variation in northern populations than in more southerly ones, consistent with recolonization after recent deglaciation. No heterozygosity values are known for the species in Alberta. The effect of reduced genetic diversity on the ability of pikas to adapt to climate change is not known (Henry *et al.* 2012a).

Given the limited range of the American Pika in Alberta and a relatively poor understanding of impacts of a changing climate on this species in Alberta, a well-designed and consistent monitoring program should be implemented in the province, both outside and inside the national parks, to provide an early indicator of changes in American Pika population numbers. Pika census methods are discussed by Morrison and Hik (2010), Millar and Westfall (2010), Timmins and Whittington (2011), Moyer–Horner *et al.* (2012), Rodhouse *et al.* (2010), and Timmins *et al.* (2013). In addition, research is needed on the climate determinants of pika distribution in Alberta. Beever *et al.* (2011) and Beever and Smith (2013) provide a research priority list that includes multiscale sampling; better understanding of the relative effects of acute cold stress, acute heat stress, and chronic heat stress; closely examining pika use of micro-climates; determining how food selectivity indices may vary under different conditions; and detailed analysis of the additive or synergistic roles played by simultaneous climate-related stressors.

Acknowledgements

Jon Ball of the Bow Valley Naturalists kindly provided me with the raw HELS data. Brad Weimann pointed me to pika location data from southern Alberta. My thanks to Amy Nixon for producing the map, providing the elevation data, and commenting on early drafts of the paper. Shawn Morrison provided insightful comments on an earlier version of the paper. The paper benefitted greatly from suggestions made by two peer reviewers and the journal editors.

This report is a product of the Biodiversity Management and Climate Change Adaptation Project (http://www.biodiversityandclimate.abmi.ca) led by the Alberta Biodiversity Monitoring Institute. The project receives its core funding from the Climate Change and Emissions Management Corporation (http://ccemc.ca).

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Received 14 November 2014
Accepted 20 May 2015

Notes

Flesh-footed Shearwaters (*Puffinus carneipes*) in the Northeastern Pacific Ocean: Summary and Synthesis of Records from Canada and Alaska

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Bond, Alexander L., and Jennifer L. Lavers. 2015. Flesh-footed Shearwaters (*Puffinus carneipes*) in the northeastern Pacific Ocean: summary and synthesis of records from Canada and Alaska. Canadian Field-Naturalist 129(3): 263–267.

Flesh-footed Shearwaters (*Puffinus carneipes*) breed in Australia and New Zealand, but spend the non-breeding season in the north Pacific Ocean. They are rare compared with most non-breeding pelagic seabirds that occur in the northeastern Pacific. Recent surveys at breeding colonies have indicated a significant population decline since the 1970s. We compiled records of Flesh-footed Shearwaters off the Pacific coast of Canada and Alaska from 1937 to 2013. Flesh-footed Shearwaters were recorded from May to October, with most sightings in August and September. Flocks of more than 20 birds have not been recorded since the 1940s, and most sightings have been of single birds, although some key areas (e.g., Goose Island Bank) have not been surveyed in recent years and previous surveys are confounded by fishing activity. Given the significant population declines at breeding colonies, the conservation status of Flesh-footed Shearwaters should be revisited.

Key Words: Flesh-footed Shearwater; *Puffinus carneipes*; British Columbia; Alaska; range limit; non-breeding season; seabird

Introduction

Flesh-footed Shearwaters (*Puffinus carneipes*) are transequatorial migrants that breed in the south Pacific and Indian Oceans from September to May, and raise a single chick each year (Marchant and Higgins 1990). Breeding colonies are located on North Island, New Zealand (Waugh *et al.* 2013), Lord Howe Island, Australia (Reid, Hindell *et al.* 2013), and around 40 islands in South and Western Australia (Lavers 2015). In addition, a small number breed on Île Saint-Paul in the Indian Ocean (Duriez and Delord 2012). Estimates of the global breeding population have ranged from 220 000 to 420 000 pairs (Marchant and Higgins 1990), but a recent reassessment and critical evaluation of historic data suggests that it may be closer to 74 000 pairs (Lavers 2015). Serious reductions in the number of breeding pairs have been reported across most of the species' range with breeding abandoned on at least six islands in New Zealand and Western Australia (Reid, Hindell *et al.* 2013; Waugh *et al.* 2013; Lavers 2015). Breeding populations are threatened by climate change (Bond and Lavers 2014), fisheries bycatch (Baker and Wise 2005; Reid *et al.* 2012), ingestion of plastic (Lavers *et al.* 2014), introduced predators (Priddel *et al.* 2006), contaminants (Bond and Lavers 2011; Lavers *et al.* 2014), and various other anthropogenic activities (Lavers 2015).

A variety of shearwaters occur off the northern Pacific coast of North America, including small numbers of Flesh-footed Shearwaters (Martin 1942; Kenyon *et al.* 2009). In light of observed population declines at breeding sites and revised global population estimates, our goal was to summarize the occurrence of Flesh-footed Shearwaters in Alaskan and Canadian waters of the Pacific Ocean using published and unpublished records.

Methods

We compiled records of Flesh-footed Shearwaters in Alaskan and Canadian waters from published sources and from researchers or pelagic tour boat operators in British Columbia and Alaska. We also obtained records from eBird, an online citizen-science repository for bird sightings (eBird 2014). We included records that were in Canadian waters or farther north (Figure 1) and contained a date and specific location. Records were screened to eliminate duplicates appearing in multiple sources or from multiple observers. For multiple records from the same location on the same day, we used the maximum count.

Results

We found 182 records of Flesh-footed Shearwaters, comprising 531 individuals, in Canada and Alaska from 1937 to 2013 (Table 1). Shearwaters were recorded between 2 May 1970 (Campbell and Shepard 1971) and 16 October 1992 (eBird 2014) with most sightings in August and September (Figure 2). Of the 182 records, 171 (94%) also included data on the number of birds seen. Of these, 101 (59%) records were of single birds, 32 (19%) were of two birds together, and the remainder

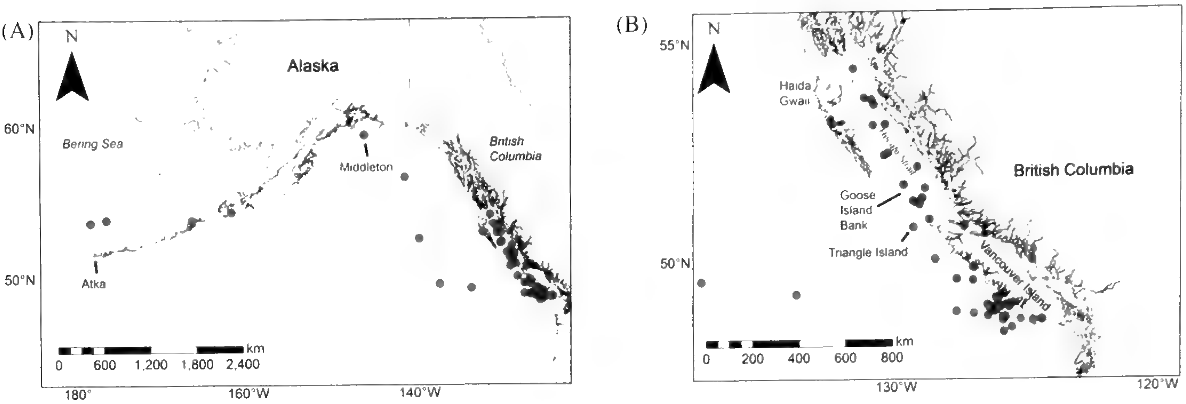

FIGURE 1. Flesh-footed Shearwaters (*Puffinus carneipes*) occur off the coast of British Columbia, and Alaska (A), particularly on the Goose Island Bank (B). Records indicated by grey circles (some records overlap or consist of multiple individuals).

TABLE 1. Summary of records of Flesh-footed Shearwaters (*Puffinus carneipes*) in Alaska and British Columbia from 1937 to 2013 by month.*

	Alaska		British Columbia	
Month	No. of records	No. of birds	No. of records	No. of birds
May			14	16
June	2	2	20	109
July	1	1	18	76
August	18	68	37	60
September	31	114	32	56
October	1	1	7	10
Unknown			1	18
Total	53	186	129	345

*Data sources: Martin (1942); Mills (1960); Martin and Myres (1969); Crowell and Nehls (1970); Campbell and Shepard (1971, 1972); Hatler *et al.* (1978); Guzman and Myres (1983); Campbell *et al.* (1990); Morgan *et al.* (1991); Cecile (2004); Kenyon *et al.* (2009); eBird (2014); North Pacific Pelagic Seabird Database (2014); various authors' unpublished data. See complete dataset for details (see *Data Availability* section).

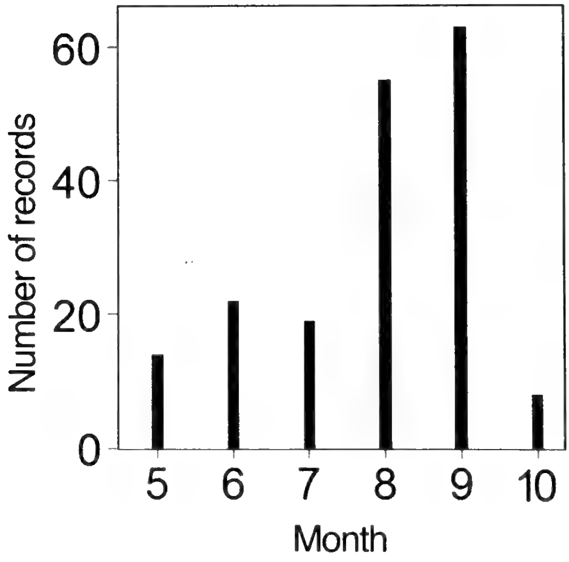

FIGURE 2. Flesh-footed Shearwaters (*Puffinus carneipes*) occur in Canadian waters between May and October, with a peak in August and September. Data are presented as the number of records (regardless of the number of birds observed) by month of record (n = 182).

were 4–60 birds, although only 11 (6%) were records of more than 10 individuals (Figure 3).

Discussion

Flesh-footed Shearwaters occur in the northeastern Pacific Ocean during the non-breeding season (May–October) and are less abundant than other shearwater species off the coast of British Columbia and Alaska (Kenyon *et al.* 2009). This made it simple to examine changes in abundance over time because, as a rare species, any records were notable and likely to be recorded.

Flesh-footed Shearwaters are well-known ship followers and highly gregarious at sea (Bartle 1974; Wahl and Heinemann 1979; Wood 1990; Freeman 1992; Baker and Wise 2005). Earlier surveys were conducted from fishing vessels (Martin and Myres 1969), which artificially inflated flock size. More recent at-sea surveys were typically carried out during oceanographic cruises, which are along established transects. Hence, time trends are difficult to assess based on current at-sea data.

Our results for Alaska are of particular interest, as Flesh-footed Shearwaters have been considered hypo-

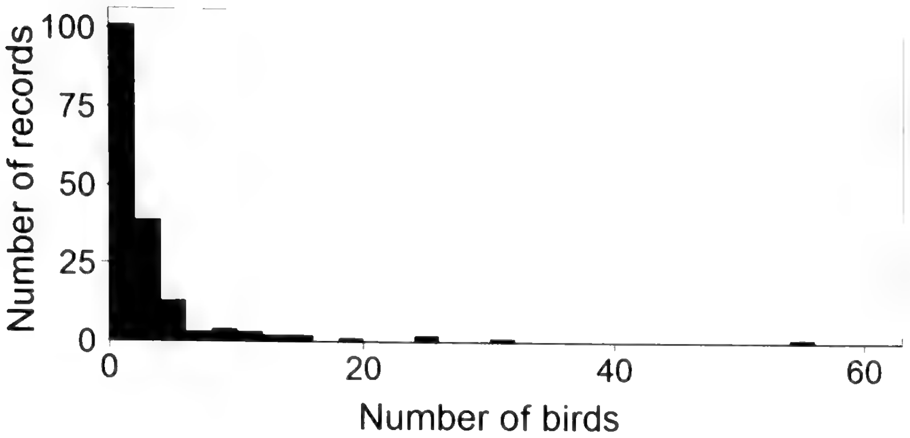

FIGURE 3. Most of the 182 records of Flesh-footed Shearwaters (*Puffinus carneipes*) in Canada have been of one or two birds (mean: 3, median: 1).

thetical in that state (Kessel and Gibson 1978; Gibson and Byrd 2007). Specifically, two records from the Bering Sea, north of Atka Island, are exceptional, and represent the most northerly records in North America. Large numbers of shearwaters spend the austral winter in the north Pacific Ocean and Bering Sea (Onley and Scofield 2007); thus, Flesh-footed Shearwaters could be easily overlooked. Current standardized surveys and databases (e.g., North Pacific Pelagic Seabird Database 2014) will be useful in documenting any northerly shift in the range of Flesh-footed Shearwaters (Hazen *et al.* 2013).

There is little evidence that direct mortality occurs in Canadian and Alaskan waters (e.g., one report of five birds taken as bycatch in experimental fisheries in the central North Pacific in the early 1990s; Elliott 2005), and no Flesh-footed Shearwaters have been recorded on beached bird surveys in British Columbia (K. Barry, personal communication), although the vast majority of birds that perish at sea never appear as beached birds (Haney *et al.* 2014). Current evidence suggests that most birds spend the non-breeding season in the western Pacific off Japan and Korea (Rayner *et al.* 2011; Reid, Tuck *et al.* 2013) or in the northern Indian Ocean (Wijesinghe 1985; Palot 2008; Powell 2009; Lavers *et al.*, unpublished data), so the North American non-breeding population represents a small, but unknown proportion of breeding birds.

Using biogeochemical markers, Lavers *et al.* (2013) predicted that most Flesh-footed Shearwaters collected off British Columbia and Washington originated from Western and South Australia and smaller numbers from New Zealand. Population estimates from Western and South Australia in the 1970s and 1980s (more than 350 000 pairs) are erroneous, and recent more rigorous surveys suggest a much smaller population (less than 36 000 pairs); therefore, the actual population trend is difficult to ascertain given the vast overestimates in the 1970s and 1980s (Lavers 2015).

An important caveat to our analysis is that we did not account for survey effort. Important areas for Flesh-footed Shearwaters, such as the Goose Island Bank, have not been surveyed in recent years (the last survey was in 1970), and most pelagic surveys take place on vessels of opportunity (Kenyon *et al.* 2009). Furthermore, we did not account for differences in the shearwaters' at-sea distribution over time, which is expected to change with oceanographic and climatic conditions (Hazen *et al.* 2013).

At-sea observations can closely mirror population trends at breeding colonies (Clarke *et al.* 2003); thus, significant population declines at Australasian breeding sites suggest that the overall abundance of this species in Canadian and Alaskan waters could have decreased. Additional surveys in key areas, such as the Goose Island Bank, are required to establish the status of Flesh-footed Shearwaters in the northeastern Pacific Ocean.

Data Availability

The complete dataset of Flesh-footed Shearwater sightings is available on figshare at http://dx.doi.org/10.6084/m9.figshare.1233374.

Acknowledgements

We thank K. H. Morgan for valuable discussions on pelagic seabirds in Canada and for providing details from the Canadian Wildlife Service's pelagic seabird database. We thank M. Bentley and A. Dorst for sharing their own observations. K. Barry (Bird Studies Canada) provided information from the B. C. Beached Bird Survey. The Natural Sciences and Engineering Research Council of Canada, W. V. Scott Charitable Trust, Birdlife Tasmania, Save our Shearwaters Foundation, and V. Wellington provided financial support during the writing of this manuscript. This manuscript was improved by comments from A. J. Gaston, K. Kuletz, K. H. Morgan, and anonymous reviewers.

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Received 18 November 2014
Accepted 3 June 2015

Tall Annual Willowherb (*Epilobium brachycarpum* C. Presl) in Ontario, Canada

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Oldham, Michael J., and Ian D. Macdonald. 2015. Tall Annual Willowherb (*Epilobium brachycarpum* C. Presl) in Ontario, Canada. Canadian Field-Naturalist 129(3): 268–272.

Tall Annual Willowherb (*Epilobium brachycarpum* C. Presl) is reported from Dryden, Kenora District, Ontario, Canada, based on a 2012 collection from a disturbed habitat where the species was presumably introduced. This is the first northern Ontario record of *E. brachycarpum* and the first Ontario record in more than 40 years. Previous Ontario records are discussed and mapped, and evidence for and against native status in the province is presented. Identification characteristics are provided, and distribution and habitat elsewhere in North America are discussed.

Key Words: Tall Annual Willowherb; *Epilobium brachycarpum*; Onagraceae; vascular plant; Ontario; Canada; distribution; status; identification

Introduction

In 1935, Merritt L. Fernald described a new variety of willowherb, *Epilobium paniculatum* Nutt. var. *subulatum* (Hausskn.) Fern., and cited four Ontario specimens: a John Macoun collection from Colpoy's Bay, Bruce County; a P. V. Krotkov collection from Hopkin's Harbour, Tobermory, Bruce County; his own collection from the La Cloche Peninsula, Manitoulin District; and another of his own collections from south of Little Current, Manitoulin Island. This variety was originally described as *forma subulata* by Haussknecht (1884) and elevated to varietal status by Fernald (1935) who noted that it had smaller flowers and longer and more slender pedicels than typical *E. paniculatum*. Later authors have generally not recognized var. *subulatum* and have used the name *E. brachycarpum* C. Presl for this species (e.g., Gleason and Cronquist 1991; Wagner *et al.* 2007; Brouillet *et al.* 2010+).

The current distribution and native status of *Epilobium brachycarpum* in Ontario are poorly known. It is regarded as a native plant in the province by Fernald (1935), Krotkov (1940), Morton and Venn (1990, 2000), and Newmaster *et al.* (1998), but as an introduction by Scoggan (1979) and Brunton *et al.* (1987). Gleason and Cronquist (1991) consider it "perhaps native in w. Que. and the Bruce Peninsula of Ont.". Marquis and Voss (1981), in their article on western species disjunct in the Great Lakes region, mention that the species has more-or-less weedy habits and may not be native in the east. In adjacent Michigan, the only occurrence (Houghton County in 2006) "seems clearly adventive in a gravel pit" (Voss and Reznicek 2012). It is considered a rare native plant in Ontario by Oldham and Brinker (2009) and ranked "SH," meaning of historical occurrence in the province as a native plant with no records in at least 20 years and possibly extirpated.

The first Ontario collection of *Epilobium brachycarpum* was made by John Macoun in 1871 (TRT) from Colpoy's Bay on the Bruce Peninsula. In his *Catalogue of Canadian Plants*, Macoun (1883–1890) stated that it was "abundant on newly cleared land at Oxendon, Colpoy's Bay, Georgian Bay, Lake Huron." Some of the early collections of Tall Annual Willowherb in Ontario are from locations and habitats that suggest it could have been native, e.g., "on top of cliff in open" (Fitzwilliam Island in 1932), "crevices and talus of hornblendic cliffs and ledges" (La Cloche Peninsula in 1934) and "about calcareous ledges in dry woods" (south of Little Current in 1934) (quotations from specimen labels). The species has apparently declined in Ontario, for unknown reasons. Krotkov (1940) commented that it was "not rare in open situations" on the Bruce Peninsula, and he collected it six times from five different sites between 1934 and 1936 (TRT). However, in more than 40 years of botanical exploration on the Bruce Peninsula, Joe Johnson (personal communication, 2014) has not seen the species there. Anton A. (Tony) Reznicek (personal communication, 2014), who has botanized in Simcoe County for more than 40 years, has seen the species only once there, in 1968, the most recent Ontario record of which we are aware before its collection in Dryden in 2012 (see below). Similarly in Manitoulin District, although there are at least four collections from the 1930s, *Epilobium brachycarpum* has not been seen on the island in more than 75 years despite extensive botanical surveys by John Morton and Joan Venn (2000).

On 29 July 2012, Ian D. Macdonald and Hugh D. J. McLean found *Epilobium brachycarpum* growing in disturbed ground at the edge of a motel parking lot in Dryden, Kenora District, Ontario. Their voucher specimen is deposited in NHIC, the herbarium of the Ontario Natural Heritage Information Centre (*I. D. Macdonald 120729d6*). At this site in northwestern Ontario, the species is likely adventive from further west where it is more common. Other than the early records from the Bruce Peninsula and Manitoulin District discussed above, we know of only one other specimen of *E. brachycarpum* from Ontario, a 1968 collection by Anton A. Reznicek from a "dry rocky roadside" in Simcoe County (DAO, MICH). Scoggan (1979) reports it from Frontenac and Renfrew Counties, but there are no supporting specimens at CAN, DAO, MICH, QK, TRT, or TRTE and the species is not included in floristic lists covering these counties (Beschel *et al.* 1970; Crowder *et al.* 1996; Coulson *et al.* 2006). Figure 1 shows the distribution of *E. brachycarpum* in Ontario.

Epilobium brachycarpum is a tap-rooted annual, North America's only annual willowherb species, and the only member of *Epilobium* Section *Xerolobium* (Wagner *et al.* 2007). In addition to its annual growth habit and occurrence in drier habitats, *E. brachycarpum* can be distinguished from other Ontario *Epilobium* species by its linear to narrowly lanceolate leaves, which are slightly falcate, glabrous, with smooth margins to widely spaced, small teeth, alternate, and occasionally in fascicles (except on the stem's lower 10 cm, where they are opposite and deciduous); white deciduous coma; short (15–30 mm) fruits; glabrous (except in the inflorescence) stems; inflorescence branches that are alternate above the middle of the stem (except in depauperate individuals); and the distinctive longitudinally exfoliating epidermis of the lower portion of the stem. Figure 2 shows the identification features of *E. brachycarpum*.

It is difficult to explain how *Epilobium brachycarpum* was documented from about 10 southern Ontario sites before 1940, some of them in remote locations and in natural habitats where an introduction would be surprising, and then not seen in the province again until 1968. Were the collections from 75+ years ago from native populations with the species more recently spreading as a weed? If the early collections were from native populations and the species is weedy in much of its range, why did it apparently die out at these sites? Could the early records have been of a different and less weedy genotype, perhaps hinted at by Fernald's recognition of it as a distinct variety? We may never know the answers to these questions, but Ontario botanists should be on the lookout for this species in areas of former occurrence as well as elsewhere in the province.

In western North America, *Epilobium brachycarpum* is widespread in a variety of open, dry, and often disturbed habitats. In western Canada, it is restricted to the southern third of the prairie provinces and southern British Columbia. In Manitoba, it has been reported on open ground and old roads near Winnipeg (Scoggan 1957) and is an S1S2 ranked ("critically imperiled to imperiled") species (Chris Friesen, personal communication, 2014). It is a common native plant in southern Saskatchewan (Harms 2006), where it is sparsely distributed in native grassland, valley slopes, and along roadway margins. In Alberta, it is an S3 ranked ("vulnerable") species (ACIMS 2014, NatureServe 2014) of dry woods, prairies, shores, montane outcrops, and roadsides (Moss and Packer 1983). In southern British

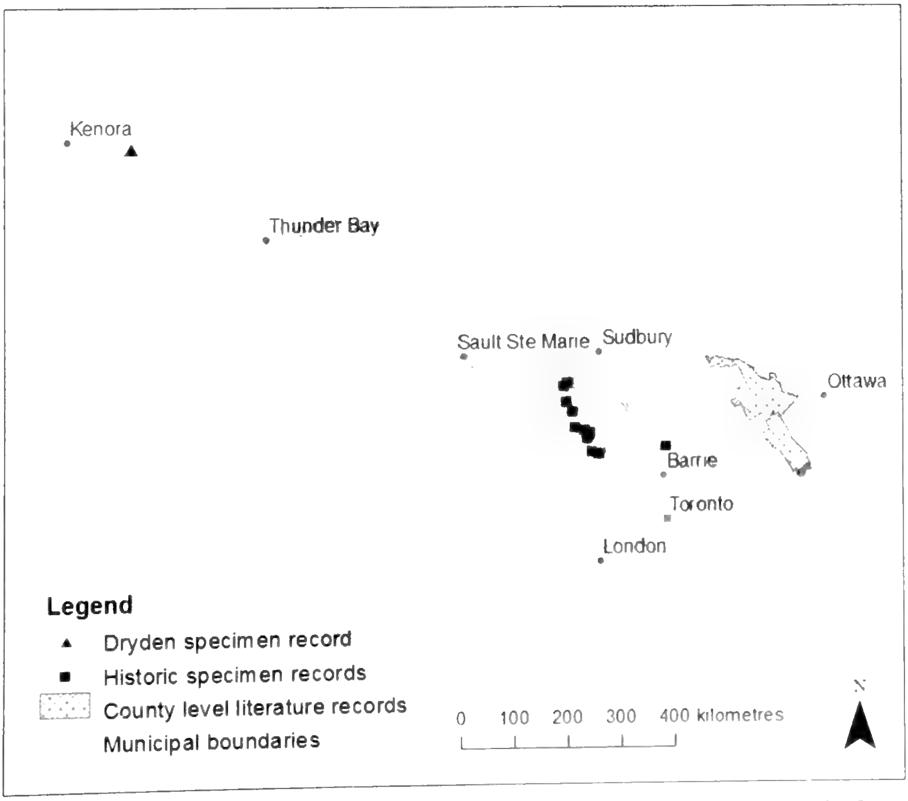

FIGURE 1. Distribution of Tall Annual Willowherb (*Epilobium brachycarpum*) in Ontario.

FIGURE 2. Tall Annual Willowherb (*Epilobium brachycarpum*). a. whole plants; b. buds; c. flower; d. seed; e. fruit; f. leaves (the leaves are folded and falcate, hence the teeth show only on one side); g. exfoliating epidermis of lower stem. The left and centre plants are STMU 4069, and that on the right is UAC 56760; all three are from British Columbia. STMU is an unofficial acronym for St. Mary's University, Calgary, Alberta.

Columbia, it is common east of the Coast-Cascade Mountains and south of Prince George in dry scrublands, forest openings, and disturbed areas in the lowland, steppe, and lower montane zones (Douglas *et al.* 1999; Douglas *et al.* 2002). Although Wagner *et al.* (2007) state that the species occurs in Yukon and Nunavut, we are not aware of records from these jurisdictions, nor is it listed from either by Scoggan (1979), Brouillet *et al.* (2010+), or NatureServe (2014). Across the western half of the United States, westward of New Mexico to Wisconsin, *Epilobium brachycarpum* occurs as a native species on dry soil of meadows, grasslands, steppe, woodlands, stream banks, roadsides, and valley slopes in both disturbed and undisturbed situations (Hitchcock *et al.* 1961; Lesica 2012). Outside North America, it also occurs in Argentina, where it was probably introduced and is typically a weed at the margins of cultivated fields (Solomon 1982; Wagner *et al.* 2007), and in Spain (Izco 1983) and Germany (Gregor *et al.* 2013), where it is a naturalized weed.

In Ontario, *Epilobium brachycarpum* is near its eastern range limits in North America (Kartesz 2013), although it has been reported from Pontiac County, Quebec (Scoggan 1979), with a supporting specimen at MT collected by Frère Rolland-Germain (no. 15884) in Deschênes, Quebec "sur la rivière Ottawa" on 14 July 1921, with no habitat information (Geoffrey Hall, personal communication, 2014). Rousseau (1968) considers it adventive in Quebec from western North America and Marie-Victorin (1995) mentions its occurrence on railway ballast in southern Quebec. *Epilobium brachycarpum* has recently been found as a weed in a railway yard in northern Kentucky (Kartesz *et al.* 1997), the most southerly of four states east of the Mississippi River where the species has been reported (the others are Michigan, Minnesota, and Wisconsin; Kartesz 2013). In future it may become more common as a local weed in eastern North America. In central Europe, *E. brachycarpum* is a rapidly-spreading invader, which Gregor *et al.* (2013) predict will become a serious agricultural weed, particularly in vineyards.

Specimens Examined

Canada, Ontario, Bruce County, Colpoy's Bay, 30 July 1871, *J. Macoun 35* (TRT 15107); between the post office and Colpoy's Bay, in rocky fields and on newly cleared land, 3 August 1871, *J. Macoun* (CAN 82713); Howdenvale, in a small depression of the dry pasture, 2 August 1926, *W. R. Watson 2959* (TRT 34241); Hopkin's Harbour, Tobermory, open rocky wood, 9 August 1933, *P. V. Krotkov 7640* (TRT 34239); Spring River [typed on original label; "Creek" added in pencil above "River," and "Valley" added in pencil after "River"], rocky wood, 14 August 1934, *P. V. Krotkov 9245* (TRT 34240); Dyer Bay, stony beach, 16 July 1935, *A. S. Pease & E. C. Ogden 24802* (MICH); Dyer Bay, brulé, 11 July 1936, *P. V. Krotkov 10735* (TRT 34243); Emmett Lake, rocky woods, 22 July 1936, *P. V. Krotkov 10734* (TRT 34242); Britain Lake, open rock wood, 19 August 1936, *P. V. Krotkov 10733* (TRT 10733); Dryer's [sic] Bay village, in old sawdust on the shore, 22 August 1936, *P. V. Krotkov 10732* (DAO 134522, TRT 34244); Kenora District, Dryden, east end of town at Best Western Motel, on south side of Trans-Canada Highway, 49°47'09.28"N, 92°49'17.27"W, unkempt dry gravelly garden along edge of parking lot of motel, associated with *Trifolium arvense, Mollugo verticillata, Silene csereii, Danthonia spicata, Pilosella aurantiaca, Anaphalis margaritacea*, 29 July 2012, *Ian D. Macdonald 120729d6 & Hugh D. J. McLean* (NHIC); Manitoulin District, south of Little Current, Manitoulin Island, about calcareous ledges in dry woods, 1934, *M. L. Fernald 3441* (GH; not seen, specimen cited in Fernald 1935); Leask Bay, South Bay, dry limestone, 18 July 1932, *W. Koelz 4155* (MICH); near Rattlesnake Harbor, Fitzwilliam Island, on top of cliff in open, 22 July 1932, *C. O. Grassl 5206* (MICH); Cloche Peninsula, crevices and talus of hornblendic cliffs and ledges, 29 June 1934, *M. L. Fernald 3440 & A. S. Pease* (GH, TRT 15100; GH specimen not seen, cited in Fernald 1935); Simcoe County, Matchedash Township, Conc. VI, Lot 17, dry rocky roadside, 27 July 1968, *T. Reznicek 947* (DAO 656859, MICH 1313523).

Acknowledgements

Paul Catling, Jennifer Doubt, Deb Metsger, and Gisele Mitrow facilitated access to specimens at the National Herbarium of Canada (CAN), the Vascular Plant Herbarium at Agriculture and Agri-Food Canada (DAO), and the Royal Ontario Museum (TRT); Peter Ball checked for specimens at the TRTE Herbarium and Dave Bradley (Ontario Natural Heritage Information Centre) photographed specimens at TRT. Geoffrey Hall and Luc Brouillet (University of Montreal) provided information on the Quebec specimen at the Herbier Marie-Victorin (MT). Tony Reznicek (University of Michigan) and Paul Catling (Agriculture Canada) provided helpful comments on an earlier draft of this manuscript, and Tony provided information on specimens at the University of Michigan Herbarium (MICH). Joe Johnson (Wiarton, Ontario) provided information on the status of *Epilobium brachycarpum* on the Bruce Peninsula. Chris Friesen (Manitoba Conservation Data Centre) provided an update on the ranking in Manitoba. Bonnie Henson of the Ontario Natural Heritage Information Centre prepared the distribution map, and Wasyl Bakowsky of the Ontario Natural Heritage Information Centre assisted with scanning Figure 2, which was prepared by Ian Macdonald.

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Received 23 October 2014
Accepted 27 February 2015

The Cost of a Prickly Diet: Incidents of Porcupine (*Erethizon dorsatum*) Quills Embedded in Wolverine (*Gulo gulo*)

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Kukka, Piia M., and Thomas S. Jung. 2015. The cost of a prickly diet: incidents of porcupine (*Erethizon dorsatum*) quills embedded in Wolverine (*Gulo gulo*). Canadian Field-Naturalist 129(3): 273–276.

The occurrence of North American Porcupine (*Erethizon dorsatum*) quills embedded in wild carnivores and domestic dogs is not rare; however, the prevalence of this occurrence and its consequences in wildlife are largely unknown. We examined 569 trapper-submitted Wolverine (*Gulo gulo*) carcasses for embedded porcupine quills. We observed quills in 4.6% of the wolverines, including all sex and age classes. We found quills throughout the body, and, in most cases, injury was not apparent. Observed complications, however, included bone proliferation and tissue damage to internal organs. Our data show that the occurrence of porcupine quills in Wolverine is not rare and demonstrate that, in a few cases, serious injuries may result from migrating quills.

Key Words: North American Porcupine; *Erethizon dorsatum*; Wolverine; *Gulo gulo*; quills

Introduction

Wolverines (*Gulo gulo*) are characterized as facultative scavengers of ungulates killed by other carnivores and opportunistic predators, responding to seasonally or locally abundant smaller prey (van Dijk *et al.* 2008; Mattisson *et al.* 2011). Occasionally, wolverines prey on North American Porcupines (*Erethizon dorsatum*; Magoun 1987; Lofroth *et al.* 2007); however, preying on porcupines may be risky.

The pelage of porcupines consists of quills, which are specialized hairs used for self-defense. Porcupine quills have a unique geometry, which serves two functions: easy penetration into tissue and strong tissue adhesion during removal (Cho *et al.* 2012). These functions are facilitated by microscopic backward-pointing deployable barbs. The barbs aid tissue penetration by creating local stress concentrations, thus reducing the force needed to cut tissue. The barbs facilitate tissue adhesion by bending radially away from the quill shaft when pulled, thus increasing frictional resistance in the tissue and making the removal of quills difficult (Cho *et al.* 2012). The combination of these two functions causes the quills to migrate deeper into the tissue, rather than fall out. Indeed, porcupine quills have been found deep in the body cavity and internal organs of other mammals (Quick 1953; Johnson *et al.* 2006).

Several species of carnivores are known to prey on or scavenge porcupine despite the risk of injury from their quills. For example, porcupines have been observed in the diet of wolverines (Banci 1987; Lofroth *et al.* 2007; Dalerum *et al.* 2009); however, the frequency of incidents of embedded quills has not been reported. Moreover, although complications from migrated porcupine quills have been documented for domestic pets (e.g., Johnson *et al.* 2006), they are largely unknown for free-ranging carnivores. Maser and Rohweder (1983) noted a lack of serious damage from porcupine quills embedded in Cougars (*Puma concolor*), Fishers (*Pekania pennanti*), and Western Spotted Skunks (*Spilogale gracilis*) that fed on porcupines.

A multi-year Wolverine carcass collection program provided us the opportunity to examine a large number of these animals for porcupine quills. Here, we quantify the occurrences of embedded porcupine quills and describe injuries attributable to migrated quills.

Methods

We obtained Wolverine carcasses from licensed fur trappers in Yukon, during the 2005–2006 to 2011–2012 fur trapping seasons. Carcasses were skinned by trappers and kept frozen at −20°C for no more than 6 months before necropsy. We conducted a gross examination of carcasses for embedded quills, along with other injuries and abnormalities. Major organs (heart, lungs, liver, kidneys and spleen) were dissected, except for the stomach and intestines, which were preserved whole and their contents were not searched for quills. We assessed the body condition of each animal based on internal fat deposits (Robitaille *et al.* 2012). We recorded the location of porcupine quills and apparent complications resulting from the quills. Quill-related injury was established by examining the immediate area around the quill for tissue abnormality and inflammation.

Results

We necropsied 569 wolverines, 26 of which (4.6%) had porcupine quills embedded in 38 unique locations. The annual number of incidents of wolverines with embedded quills ranged from zero to seven, increasing in the last 2 years. Porcupine quills were present in all sex and age classes of wolverines (Table 1). No significant differences in the percentage of wolverines with porcupine quills were found between age classes ($\chi^2 = 3.95$, $P = 0.556$) or sexes ($\chi^2 = 5.17$, $P = 0.395$).

Porcupine quills were embedded in various body regions of wolverines (Table 2). Quills were most often (53%) found in the abdominal cavity and associated organs, where they had presumably migrated through the stomach. Typically, quills were either sticking out

TABLE 1. The incidence of North American Porcupine (*Erethizon dorsatum*) quills in Wolverine (*Gulo gulo*) harvested in Yukon during seven winters (sample sizes in parentheses). Young animals were <2 years old.

	Number of wolverines with embedded quills (*n*)						
Wolverine sex and age class	2005 2006	2006 2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012
Sex							
Male	2 (48)	3 (50)	3 (66)	0 (55)	2 (65)	4 (49)	3 (45)
Female	1 (20)	0 (27)	0 (27)	0 (20)	2 (36)	2 (24)	4 (36)
Age-Class							
Young	1 (37)	3 (50)	1 (48)	0 (34)	2 (68)	4 (46)	4 (53)
Adult	2 (30)	0 (26)	2 (43)	0 (39)	2 (29)	2 (26)	3 (27)
Total	3 (68)	3 (77)	3 (93)	0 (75)	4 (101)	6 (73)	7 (81)
Overall %	4.4	3.9	3.2	0	4.0	8.2	8.6

Note: Age class of some specimens were not able to be determined, and consequently were excluded from age class summary in table.

TABLE 2. General location of North American Porcupine (*Erethizon dorsatum*) quills embedded in Wolverine (*Gulo gulo*) harvested in Yukon during seven winters, 2005–2012.

Location of quill	No. of events
Torso and legs	9
Head	7
Abdominal fat deposit	6
Kidney	5
Stomach (external)	4
Abdominal cavity (floating)	2
Heart	1
Liver	1
Lung	1
Spleen	1
Diaphragm	1

from the stomach or embedded in the intestinal fat deposits, but they were also observed in the kidneys, liver, spleen, and diaphragm. Quills were also commonly (42%) located in the torso and legs, probably indicating the initial contact with the porcupine. Two incidents (5%) involved quills embedded in the heart and lungs, where they could have migrated either through skin or via ingestion. Typically, when quills were found in a wolverine, the range was one to five.

Complications from migrated porcupine quills were often not apparent, and most affected wolverines appeared to have a normal body condition. Quills embedded in muscle tissue or floating within a body cavity were not associated with any signs of complication. However, quills that were embedded in organs, such as kidney, liver, lung, or heart, had often caused local tissue damage, such as hemorrhaging, inflammation, congestion, and adhesions. In one instance, a quill was encapsulated in the heart of a juvenile male, and this animal also suffered from an intussusception of the colon resulting in intestinal necrosis. Quills were also found in the kidney and abdominal cavity. This animal was emaciated, but how much the quills contributed to his poor condition is unknown. Another noteworthy case involved a juvenile female with quills embedded in her shoulder, sternal and mesentery fat deposits, liver, and lung. The liver was locally inflamed and had hemorrhaged around the quill; the affected lung was congested and showed signs of pneumonia. This wolverine appeared lean, but the effect of the quills on her physical condition is unknown. Two other notable cases of complications involved bone proliferation, where quills had penetrated the periosteum of long bones. In these cases, the quills were encapsulated within the bone, which displayed obvious malformations (Figure 1).

Discussion

Porcupine has been reported in the diet of wolverines (Banci 1987; Lofroth *et al.* 2007; Dalerum *et al.* 2009) as well as other carnivores (Pollack 1951; Quick 1953; Daniel 1960; Maser and Rohweder 1983), although in low frequencies. Our data do not reflect the frequency of porcupines in the diet of wolverines, because the outcomes of encounters may have included consumption without acquiring quills or engagement without consumption. Further, our sample was based on trapped wolverines and may not be representative of the overall population. The incidence of porcupine quills in wolverines is likely higher than reported here, because we would have missed quills attached to the skin, which was removed by trappers before they submitted a carcass. Regardless, a substantial percentage of the wolverines in our sample (~5%) had encountered or consumed a porcupine, suggesting that such encounters are somewhat common, with no differences among sex or age classes.

To the best of our knowledge, no studies have examined the implications of embedded porcupine quills on the host wildlife species, presumably because injured wildlife are rarely encountered, diagnosed, or treated. A study of quill injuries in domestic dogs indicated complications in 32 (10.8%) of 296 cases, and increasing time between quill injury and initial treatment was associated with an increased risk of complications (Johnson *et al.* 2006). Consequently, the risk of complications in wildlife is probably higher. However, wild carnivores may also have learned to kill and process porcupines with minimal exposure to quills (Maser and

FIGURE 1. North American Porcupine (*Erethizon dorsatum*) quill embedded in tibia (A) and fibula (B) of wolverines (*Gulo gulo*). Bone proliferation around the quill had enclosed the quills holding them tightly in place. Photos: K. Melton.

Rohweder 1983). Severe injuries related to quills have been reported in some birds, including Golden Eagle (*Aquila chrysaetos*; Lano 1922), Great Horned Owl (*Bubo virginianus*; Wiley 1969), and Gray Jay (*Perisoreus canadensis*; Griffin 1952). These species do not typically feed on porcupines, and these reports probably represent isolated events in which inexperienced birds attempted to prey on or scavenge them.

Porcupine quills can cause a variety of immediate and delayed complications as documented for domestic carnivores, such as dogs. Common complications in dogs following a porcupine encounter include localized pain, inflammation, and discharge (Johnson *et al.* 2006). However, serious delayed complications can also occur in domestic dogs, such as quill migration into the brain (Sauve *et al.* 2012), joints (Brisson *et al.* 2004), and central nervous system (Schneider *et al.* 2010). Quill migration, with attendant complications in some cases, was similarly observed in our sample of wolverines.

The percentage of wolverines with embedded porcupine quills doubled over the last 2 years of our study. Reasons for this increase are unclear. No scientific data on porcupine population trends during our study were available. Anecdotal observations suggest that porcupine abundance was stable or slowly increasing through much of Yukon during this time. The impact of an apparently stable or slowly increasing porcupine population on our observed rates of quill injuries in wolverines is unknown. Porcupine is an infrequent diet item for wolverines, whereas Snowshoe Hare (*Lepus americanus*) is a main prey item of wolverines in Yukon (J.-F. Robitaille, unpublished data), and, typically, predators that rely on Snowshoe Hare switch to alternative prey when hare populations are low (Keith and Cary 1991). The increase in incidents of quills in wolverines that we observed was in synchrony with a low phase in the Snowshoe Hare cycle in the region (Krebs *et al.* 2014). It may be that wolverines will more readily prey on porcupines when Snowshoe Hares are scarce. However, study throughout the complete hare cycle would be needed to evaluate this hypothesis.

Acknowledgements

We thank all the Yukon trappers who kindly contributed Wolverine carcasses to our study. We also thank the many assistants who contributed to necropsies, particularly Jane Harms, Meghan Larivée, Michelle Oakley, René Rivard, Jean-François Robitaille, Helen Slama, Kim Melton, and Mary Vanderkop.

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Received 4 December 2014
Accepted 7 May 2015

Further Evidence of Cougars (*Puma concolor*) in Ontario, Canada

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Rosatte, Rick, Lil Anderson, Doug Campbell, Christine Ouellet, Brad White, Tasnova Khan, Paul Van Schyndel, Randy Pepper, Christy MacDonald, Wil Wegman, and Mike Allan. 2015. Further evidence of Cougars (*Puma concolor*) in Ontario, Canada. Canadian Field-Naturalist 129(3): 277–281.

Previous studies have indicated that Cougars (*Puma concolor*) were present on the Ontario landscape from 1935 to 2010. During 2012 and 2014, six pieces of evidence were collected that verified that Cougars were present in Ontario at that time. (1) A scat found near Collingwood, Ontario, was confirmed as containing Cougar DNA. (2) A Cougar was photographed by a member of the public near Pefferlaw, Ontario, and the photograph was proven to be authentic. (3) A Cougar was photographed near Kenora, Ontario. (4) A Cougar was observed near Kenora, Ontario, and tracks confirmed the sighting. (5) A Cougar attacked a dog near Bracebridge, Ontario; the animal was subsequently shot by police and DNA evidence indicated that it had at one time been in captivity. (6) A cougar was photographed and later captured near Grafton, Ontario.

Key Words: Cougar, DNA, endangered, Ontario, puma, *Puma concolor*

By the early 20th century, Cougars (*Puma concolor*) had apparently been extirpated from much of their historical range in eastern North America including Ontario, Canada (Bolgiano and Roberts 2005). However, Gerson (1988) reported documented sightings of Cougars in Ontario during 1935–1983. Rosatte (2011a) provided further evidence that Cougars existed on the Ontario landscape between 1991 and 2010. DNA analysis has confirmed the existence of free-ranging Cougars in Ontario and Quebec and most of eastern Canada (Cumberland and Dempsey 1994; Bertrand *et al.* 2006; Mallory *et al.* 2012; Le Duing *et al.* 2013). In Ontario, Cougars are classified as an endangered species (OMNR 2010). In this paper, we provide additional evidence, collected during 2012–2014, that supports the view that free-ranging Cougars occur in Ontario.

On 7 June 2012, a scat was found by a member of the public near Collingwood, Ontario (44.475°N, 80.275°W) (Figure 1). Swabs of the scat were submitted to the Natural Resources DNA Profiling & Forensic Centre (NRDPFC) at Trent University, Peterborough Ontario, for DNA analysis. To determine the species, a region of the cytochrome B gene within the mitochondrial DNA was amplified (30 cycles at annealing temperature 54°C) using Cougar-specific primers, PumaCB-F (5′-CCG AGA AGR TAT GGA GCC ATA A-3′) and PumaCB-R (5′-CTA TAC ATC AGA CAC AAT GAC TGC C-3′). This amplification is sensitive down to 10 pg of DNA. The fragment size generated using primers PumaCB-F and PumaCB-R was 121 base pairs (without the primer sequences) and 170 base pairs (with the primer sequences). The amplified DNA was subsequently sequenced on an Applied Biosystems 3730 DNA Analyzer (Life Technologies, Burlington,

FIGURE 1. Scat found by a resident near Collingwood, Ontario, in June 2012, contained Cougar (*Puma concolor*) DNA. Photo: Jeanette Varga-Papp.

Ontario, Canada) and the resulting sequences were analyzed using the phylogenetic software package MEGA5.2 (Tamura *et al.* 2011). The sequences were compared to several cytochrome B sequences in the National Centre for Biotechnology Information database by conducting a Basic Local Alignment Search Tool (BLAST) search. DNA from the scat aligned with and was most closely related to *Puma concolor* (Cougar) (GenBank accessions KC567624 and JN999997).

In mid-January 2013, a member of the public reported that he had taken a photograph of a Cougar near Pefferlaw, Ontario, (44.315°N, 79.203°W) at about 0100 (Figure 2). A site visit by Ontario Ministry of Natural Resources (OMNR) staff revealed a few inconsistencies with vegetation in the original photo but these differences may have been due to the fact the photo was taken at night. There was no evidence to indicate that the photo had not been taken on the property, and an interview with the photographer suggested that the photo was valid. Using the tree in the photo as a source of scale, we estimated that the animal was about 110 cm head and body length and 66 cm in height along its back. These dimensions were in the range for North American Cougar populations (Logan and Sweanor 2001). The large size ruled out smaller cats, such as Bobcat (*Lynx rufus*) (Anderson and Lovalo 2003), which also occur in southern Ontario (Rosatte 2011b; Naughton 2012). Six Cougar experts from across North America confirmed that the animal in the photo was a subadult Cougar.

On 31 October 2013, a Cougar was photographed by a member of the public, as it snarled and growled at four dogs at a private residence about 5 km northeast of Kenora, Ontario (49.775°N, 94.415°W). OMNR staff (L. Anderson) viewed the photo and confirmed that the animal was a Cougar. However, the photographer would not provide OMNR with an electronic copy of the photo at that time. Coincidently, on 15 November 2013, a Cougar was observed by a trapper (from about 65 m distance) about 17 km northeast of Kenora, Ontario, (49.817°N, 94.254°W). The animal was described as "deer-coloured" with a long tail, and about the size of an adult shepherd dog.

OMNR staff visited the location of the sighting and photographed tracks left by the animal in the snow. The tracks were about 9.0 cm in diameter and had characteristics that were consistent with a Cougar (Rosatte 2011a) (Figure 3). The distance from the heel of the hind foot to the toe of the front foot when the Cougar was walking on a snow-covered fallen tree trunk was 158 cm. When walking on flat ground across a roadway, the stride distance from the front of the toe on the right hind foot to the front of the toe on right front foot was about 85–90 cm. This stride distance was consistent with Cougar as opposed to Canada Lynx (*Lynx canadensis*) or Bobcat (Montana Fish, Wildlife & Parks 2015: 14). The location of the tracks was about 12 km east of the site where the photo of a Cougar was taken on 31 October. Given the tremendous mobility of Cougars, it is possible that these sightings and tracks were from the same animal.

Additional evidence involves a Cougar that had once been in captivity. During early July 2012, a number of Cougar sightings in the greater Bracebridge, Ontario, area were reported to the Ontario Provincial Police, Bracebridge detachment. On 7 July 2012, a Cougar attacked a dog (a German shepherd mix) in a residential yard about 15 km north of Bracebridge, near Utterson (45.211°N, 79.329°W). The Cougar was shot by the police because of the potential danger to the public (Figure 4) and the dog was euthanized as a result of its injuries. The Cougar was examined at the scene by OMNR staff and police, and it appeared that the front claws were missing. The rear claws were present, but

FIGURE 2. Photo of a Cougar (*Puma concolor*) taken near Pefferlaw, Ontario, in January 2013. Photo: Mike Wahrer and Al Dixon.

FIGURE 3. Photo of tracks where a Cougar (*Puma concolor*) was observed near Kenora, Ontario, on 15 November 2013. Photo: Lil Anderson.

were well worn suggesting the animal may have been a captive animal that had escaped or was released.

The carcass was frozen at the Bracebridge OMNR office and transported on 10 July 2012 to the Canadian Cooperative Wildlife Health Centre (CCWHC), Guelph, Ontario, for post-mortem analysis. On 11 July 2012, hair and muscle samples were submitted to the NRDPFC for genetic analysis. During 2013, samples were also shipped to the United States Forest Service, Rocky Mountain Research Station, Wildlife Genetics Laboratory, in Missoula, Montana, in an attempt to determine the geographic origin of the Cougar by comparing its DNA profile with profiles in a database of Cougars from the western United States.

The post mortem at the CCWHC revealed that the Cougar was a young (determined by tooth wear) adult female weighing 48 kg that had died due to gunshot trauma. Extremely large amounts of subcutaneous and internal fat were found, the muscle mass was normal, and there was slight wear on the teeth. The Cougar was a healthy animal, in excellent body condition, with no evidence of significant pre-existing disease. The brain tested negative for rabies by the fluorescent antibody technique. The liver was olive-green with a slightly fatty texture. The gallbladder was full, and the stomach contained grass, hair, and two pieces of fabric. Most of the intestinal tract was empty, and lesions were not apparent in the liver, thyroid, tonsil, esophagus, small

FIGURE 4. Photo of a dead adult female Cougar (*Puma concolor*) that attacked a dog near Bracebridge, Ontario, on 7 July 2012. Photo: C. MacDonald.

intestine, stomach, heart, or brain (as determined by histologic examination). A single large *Sarcocystis* cyst was observed within the tongue muscle and a few small foci of interstitial inflammation were found in the kidneys. A thick band of acellular eosinophilic material (possibly amyloid) occurred at the corticomedullary junction of the adrenal glands, and the mammary gland was inactive. The Cougar was pregnant, with an approximately 14-cm (crown to rump) fetus present. No tattoos, microchips, or other identifying markings were found; however, the lack of claws on the forefeet indicated probable surgical removal. The body condition and absence of claws on the front feet suggested that the animal had recently been captive and cared for.

The geographic origin of the adult female Cougar is unknown. However, there was a large exotic cat facility 300 m from where the Cougar had been shot. Blood samples collected from two captive male Cougars at that facility in October 2012 revealed that they could be related to the adult female Cougar at the sibling level. In addition, one of the male Cougars could not be excluded as father of the fetus based on examination of six microsatellite loci at the NRDPFC. Regarding the strength of the parentage assignment, in this case, we were only concerned with distinguishing between two possible fathers of the fetus. One of the male Cougars was excluded at one of the six loci, whereas the other could not be excluded at any of the six loci. This evidence showed that the adult female had been in captivity at some time, during which she became impregnated. The owner of the exotic cat facility subsequently pled guilty to charges relating to the case.

Analysis of the samples sent to the Wildlife Genetics Laboratory in Montana was inconclusive with respect to the geographic population from which the adult female and the two male Cougars originated. This result may have been due to the fact that these Cougars originated from a mixture of populations or from a population the laboratory had yet to sample, e.g., South American genotype Cougars. The Wildlife Genetics Laboratory database contained genotypes from 1770 animals collected from South Dakota, North Dakota, Nebraska, Montana, Wyoming, Colorado, Idaho, New Mexico, Arizona, Texas, Florida, and Oregon.

About two weeks before the shooting of the Cougar in Utterson, a Cougar was observed during the evening by several people about 5 km south of Utterson near Port Sydney, Ontario. Given the movement capabilities of Cougars (up to 50 km/night; Rosatte 2011a), it is possible that these sightings involved the same Cougar. Regardless, the implications of a formerly captive pregnant adult female Cougar roaming central Ontario is significant from a genetic perspective (although its chances of surviving in the wild are unknown).

Last, a Cougar was observed and photographed near Grafton, Ontario (43.993°N, -78.023°W) by a member of the public on 10 July 2014 (Figure 5). On 11 July, OMNR staff captured the animal using a baited bear trap, and it was transported to a zoo in Peterborough, Ontario, for assessment. It was determined to be a healthy young male Cougar, about three years of age, with its claws intact. The origin of the Cougar is unknown (as of 21 July 2014), but its disposition (fairly tame) led to the suspicion that it was in captivity at some time.

The new data presented here provide further support of the view that Cougars currently exist on the Ontario landscape. As in previous studies, it is unknown

FIGURE 5. Photo of a Cougar (*Puma concolor*) near Grafton, Ontario, on 10 July 2014. Photo: Jean Wilson.

whether the animals were escaped or released captives, immigrants from western North America, native Cougars, or a genetic mixture of several sources, as was found in Quebec and New Brunswick (Rosatte 2011a; Le Duing *et al.* 2013). The Cougar that was shot near Bracebridge, Ontario, provides evidence to support the theory of Rosatte (2011a) that escaped or released Cougars and their progeny are one of the sources of Cougars in Ontario. It also provides evidence that escaped or released animals are among the Cougars that are currently on the Ontario landscape.

Acknowledgements

Special thanks to Jeanette Varga-Papp, who submitted scat swabs for DNA analysis; Mike Wahrer, who took the photograph of the Cougar near Pefferlaw, Ontario; Richard Anderson, who reported the Cougar sighting and tracks near Kenora, Ontario, and Jean Wilson, who took the photo of the Cougar near Grafton, Ontario. The post mortem on the Cougar that was shot was performed at the Canadian Cooperative Wildlife Health Centre, Guelph, Ontario. Thanks to Georgian Animal Hospital staff, Dr. Hillary Turnbull and Tammy Perks, and OMNR, Parry Sound District staff, Todd Cairns, for collecting blood samples from the two adult male Cougars at the exotic cat facility in Utterson, Ontario. DNA analysis was conducted by the Natural Resources DNA Profiling and Forensic Centre, Trent University, Peterborough, Ontario. Samples were also sent to the United States Forest Service, Rocky Mountain Research Station, Wildlife Genetics Laboratory, Missoula, Montana, for genetic profiling.

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Received 14 January 2014
Accepted 31 October 2014

Observations of the Use of Buildings by Free-ranging Elk, *Cervus canadensis*, in Prince Albert National Park, Saskatchewan

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Brook, Ryan K. 2015. Observations of the use of buildings by free-ranging Elk, *Cervus canadensis*, in Prince Albert National Park, Saskatchewan. Canadian Field-Naturalist 129(3): 282–284.

Elk (*Cervus canadensis*) are habituated to humans and associated buildings in many national parks in North America. During the summers of 2012–2014, observations were made of Elk standing on the decks of cabins and entering campground cook shelters in and around the town of Waskesiu in east-central Prince Albert National Park, Saskatchewan. These appear to be the first documented observations of Elk entering buildings intentionally. The reason for this behaviour is likely a combination of the animals seeking areas safe from wolves, thermal cover, and relief from biting insects.

Key Words: Elk behaviour; *Cervus canadensis*; Elk; habituation; buildings; Prince Albert National Park; Saskatchewan

Habituation occurs when wildlife decrease their response or cease to respond to a repeated stimulus that is normally not accompanied by positive or negative reinforcement (Thorpe 1956). This may include a significantly reduced fear of people and human-made environments (Thompson and Henderson 1998; Whittaker and Knight 1998). In national parks in North America, where wolves are present but hunting is forbidden, Elk (*Cervus canadensis*)[1] have often become habituated to humans and frequent areas near roads and buildings to avoid predation (Dekker and Slatter 2009). In many cases, this habituation has become pronounced, most notably in unhunted populations. For example, human visitors to Yellowstone National Park are injured by Elk every year by approaching habituated Elk too closely (Conover 2001). Although Elk use of areas close to roads and human dwellings has been well documented, I am not aware of any published reports of Elk entering buildings. This note includes such a report.

I observed and photographed free-ranging Elk in the town of Waskesiu and the adjacent campgrounds in east-central Prince Albert National Park, Saskatchewan (53°56.1'N, 106°04.2'W). This area is dominated by mature spruce forest that last burned in 1919, mixed with patches of deciduous forest (Parks Canada 2011).

During the summers of 2012–2014, observations were made of Elk standing on the decks of cabins and entering campground cook shelters. Specifically, on 15 July 2012 at 1530, I observed an adult female Elk on a deck next to the front door of a cabin (Figure 1A). On 9 July 2013 at 1745, I saw another adult female Elk on the deck of a different cabin (Figure 1A). In both cases, the cabin owners were absent, but people were walking nearby and vehicles were driving along the roads directly adjacent to the cabins used by the Elk. Further, I observed regular use of two campground cook shelters in the Beaver Glen campground near Waskesiu by a group of two adult male Elk (both with four-point antlers in velvet), one adult female, and two juveniles (Figure 1B–D) almost continuously during daylight hours on 12 and 13 July 2014. The animals remained inside the cook shelters for 8–49 minutes at a time, moving out to feed within 90 m of the shelter for 17–44 minutes, before returning to the shelter. Discussions with local cabin owners indicated that this behaviour is not uncommon during the summer in and around Waskesiu. All of these observations were made when the ambient temperature was above 20°C and the activity of biting flies, including mosquitoes (*Culex* sp.), black flies (*Simulium* sp.), and horseflies (*Chrysops* sp.), was high.

These observations of free-ranging Elk using human dwellings represent extreme examples of their habituation to humans. This behaviour is most likely a result of predator and insect avoidance as well as seeking thermal cover and forage access. Elk herds in Jasper National Park (Dekker *et al.* 1995) and Banff National Park (McKenzie 2001), Alberta, are both concentrated near the park town sites where large carnivores are less common. Although rarely studied in Elk, biting flies have been reported to have a considerable impact on ungulates, disrupting feeding and resting (Downes *et al.* 1986) and prompting animals to seek relief areas that are cooler and vegetation free and where biting flies are less abundant (Boertje 1981). Buildings provide significant thermal cover in the form of shade, lower ambient temperature, reduced absorption of solar radiation by animals, and direct conduction of body heat when the animal is lying on cement. Forage may also play a role, as gardens and other high-quality fertilized and watered

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[1] The taxonomy of the Red Deer-Elk-Wapiti complex in the Cervidae family has yet to be fully resolved. I use *Cervus canadensis* here, following the IUCN Redlist (Lovari *et al.* 2008), based on the recommendations of Geist (1998) and recent genetic work by Randi *et al.* (2001) and Ludt *et al.* (2004).

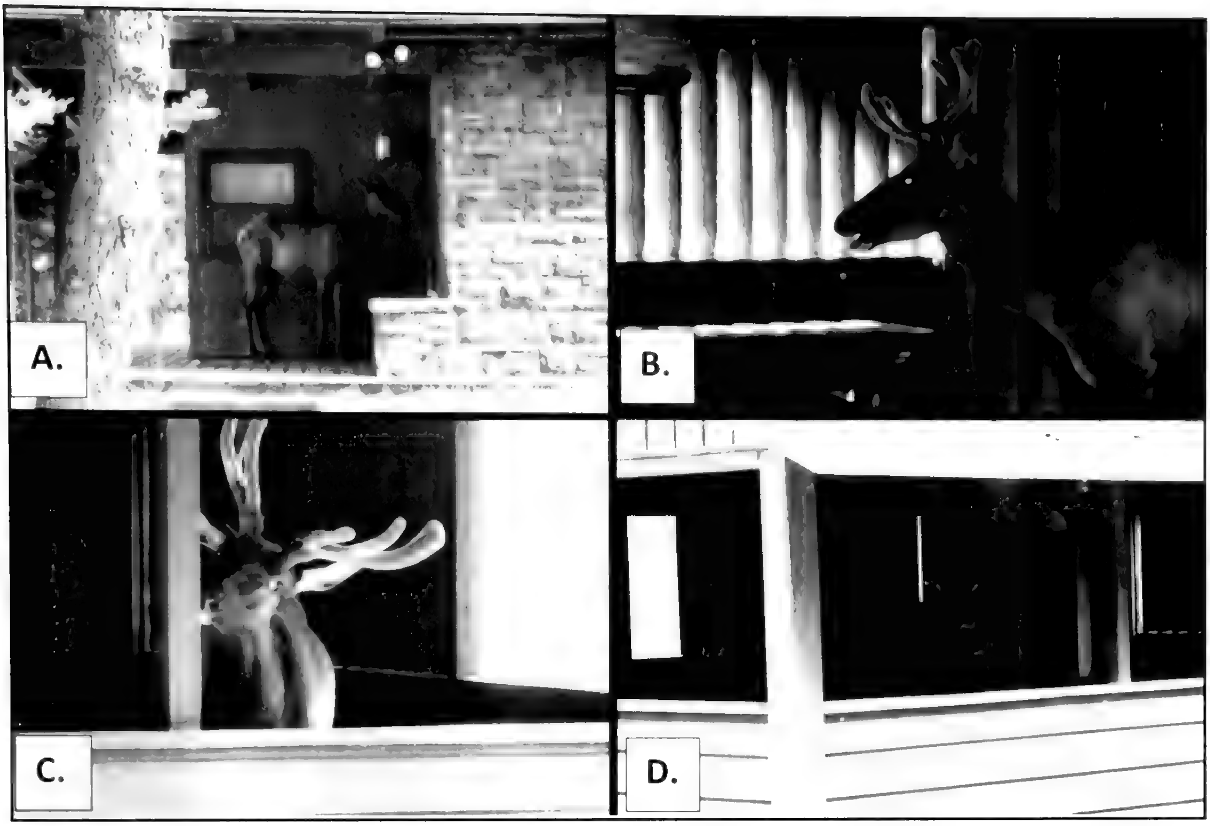

FIGURE 1. (A) Free-ranging adult female Elk (*Cervus canadensis*) on the porch of a cabin in Waskesiu, Prince Albert National Park, Saskatchewan (13 July 2012). (B) Male Elk in a cook shelter in the Beaver Glen campground near Waskesiu (12 July 2014). (C) Male Elk in another cook shelter (13 July 2014). (D) One female and one male Elk in a cook shelter (13 July 2014). Photos: Ryan K. Brook.

plants are available near the buildings. The use of buildings that are vegetation free may involve a trade-off between seeking forage and avoiding predation. McKenzie (2001) found that Elk in Banff made greater use of urbanized areas in both summer and winter and that urban Elk had a significantly higher rate of survival that Elk using wilderness areas.

The use of buildings by Elk is viewed positively by many park visitors who enjoy seeing and approaching Elk to photograph and observe them. I regularly observed people approaching within 5 m of the Elk that were using the dwellings. However, this Elk behaviour could become an increasing nuisance as these animals defecate and feed on flower gardens and lawns. Habituated Elk can also become a public health risk and are associated with significant liability issues. Further research and monitoring is required to characterize the frequency, timing, and extent of habituation in the local Waskesiu Elk herd. A wide range of management options is available to deal with habituated Elk; they must be non-lethal to be used in a national park and can include hazing to scare Elk and instill a greater fear response toward people and buildings. Other options include translocation of problem animals, application of chemical repellants, and fencing (Walter *et al.* 2010).

Acknowledgements

This study was funded by the University of Saskatchewan. The Wildlife Ecology and Community Engagement Lab provided ongoing input and support.

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Received 19 July 2014
Accepted 6 June 2015

Impact of a Major Forest Blowdown Event on Breeding of Ancient Murrelets, *Synthliboramphus antiquus*, at a Colony in Haida Gwaii, British Columbia

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Gaston, Anthony J., Jake Pattison, and Ainsley Brown. 2015. Impact of a major forest blowdown event on breeding of Ancient Murrelets, *Synthliboramphus antiquus*, at a colony in Haida Gwaii, British Columbia. Canadian Field-Naturalist 129(3): 285–289.

In the winter of 2010–2011 a large storm blew down an area of about 18 ha of mature coastal rainforest on East Limestone Island, Haida Gwaii, British Columbia. The area supported part of a breeding colony of Ancient Murrelets (*Synthliboramphus antiquus*). Observations of the timing of chick departures from this section of the colony in 2012 and 2013 suggested that daily timing of chick departures were delayed, on average, by about 30 min, compared with earlier years. This delay may have been caused by debris from the blowdown impeding the progress of chicks over the ground. A sharp decrease in the number of chicks leaving the blowdown area in 2014 may signify that some breeding pairs left the area following reduced breeding success.

Key Words: Ancient Murrelet; *Synthliboramphus antiquus*; Haida Gwaii; Queen Charlotte Islands; chick departure; blowdown; breeding success

Introduction

The offshore islands of Haida Gwaii (Queen Charlotte Islands, British Columbia), support an evergreen forest of Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), Sitka Spruce (*Picea sitchensis* (Bongard) Carrière), and Western Redcedar (*Thuja plicata* Donn ex D. Don) (Pojar 2008). Trees in sheltered lowland valleys on the larger islands (e.g., Louise, Lyell, and Burnaby) reach 60 m in height, while even the smallest, most exposed islands (< 100 ha) support trees up to 40 m high. On exposed headlands, an open forest of low Sitka Spruce (< 25 m tall) with grass understory is typical. Many of the smaller, forested islands support breeding colonies of burrow-nesting seabirds, including auks (Cassin's Auklet [*Ptychoramphus aleuticus*], Ancient Murrelet [*Synthliboramphus antiquus*], and Rhinoceros Auklet [*Cerorhinca monocerata*]), and storm-petrels (Fork-tailed Storm-Petrel [*Oceanodroma furcata*] and Leach's Storm-Petrel [*Oceanodroma leucorhoa*]) (Rodway 1990).

Although the coastal forests of Haida Gwaii are very resistant to wind damage, periodic storms with hurricane force winds occasionally result in serious blowdown events. These effects are especially likely when the strongest wind gusts emanate from an unusual direction. Patches of regenerating trees give ample evidence of past events, and this regime of frequent disturbance limits the maximum age of stands there, compared with more protected interior forests.

A major blowdown event occurred on islands in northern Laskeek Bay during the winter of 2010–2011, when two large storms passed across the archipelago. The first storm, which occurred in the fall, was accompanied by hurricane-force winds from the southwest, and the second, in late February, by equally strong winds from the northeast. Winds of such force from both these directions are uncommon on Haida Gwaii; the typical direction of storm-force winds is from the southeast (Thomson 1989). As a result of these storms, trees were broken off or uprooted over about a third of the area of East Limestone Island (Figures 1 and 2), as well as sections of forest on several adjacent islands. The affected area included about half the area of the Ancient Murrelet breeding colony on East Limestone Island.

The breeding biology of Ancient Murrelets at East Limestone Island has been studied since 1990 by the Laskeek Bay Conservation Society. Making use of the long-term data set accumulated by the society before the storm, this paper describes some effects of the blowdown event on the breeding of Ancient Murrelets.

Study Area

East Limestone Island, off the south-east corner of Louise Island (54°24'25"N, 131°36'44"W) is 48 ha in extent, with an uneven topography rising to about 50 m above sea level. Most of the island supports typical Sitka Spruce–Western Hemlock–Western Redcedar forest, but a swath of the south coast is covered in Red Alder (*Alnus rubra* Bongard). In the interior of the island, a small number of large trees have apparently remained standing through several cycles of blowdown. The island has never been exposed to industrial logging activities, although a small number of trees may have been taken opportunistically from shorelines in the past. Understory vegetation is sparse or absent over most of the island because of intensive deer browsing (Stockton *et al.* 2005). Ancient Murrelets nest in burrows over

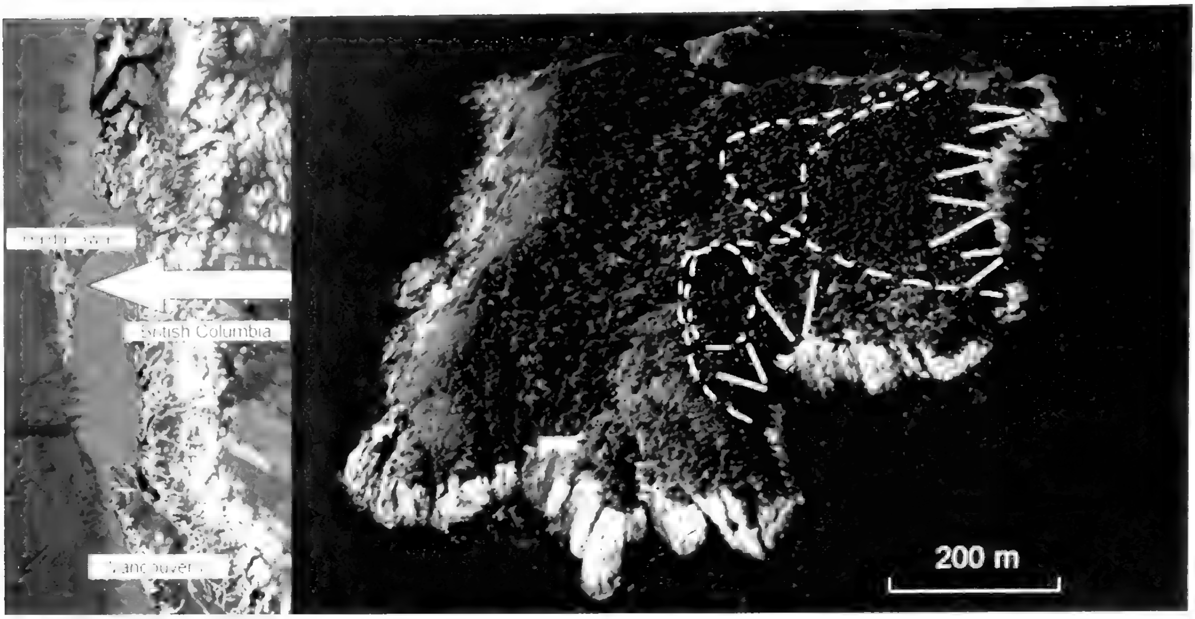

FIGURE 1. Aerial view of East Limestone Island, Haida Gwaii, British Columbia, seen from the east. The area of the blowdown is enclosed by white dashes, the Ancient Murrelet (*Synthliboramphus antiquus*) breeding area is north and east of the yellow dashes, and the original chick funnels are shown in blue. Left inset map shows the position of East Limestone Island on the coast of British Columbia. Images from Google Earth, data SIO, NOAA, US Navy, NGA, GEBCO ©2015 Cnes/Spot image. Image ©2015 DigitalGlobe.

FIGURE 2. A section of the forest on East Limestone Island, Haida Gwaii, British Columbia, (A) before the storm in winter 2010–2011 and (B) after the storm. Photos: Laskeek Bay Conservation Society.

about half the island, mainly in an arc along the east and north coasts extending inland up to 300 m (Figure 1). In 2006, the Ancient Murrelet population was estimated at 506 breeding pairs (Lemon 2007).

Methods

One- to two-day old Ancient Murrelet chicks leave the burrow at night and make their way through the forest to the shore. Chicks depart after dark, usually between 2300 and 0130, and do so only after the arrival of the off-duty parent, so that the entire family leaves the burrow together (Jones *et al.* 1987). The parents then fly directly to the sea where they rendezvous with the chicks (Gaston 1992). The transit from burrow to shore normally takes 30–60 minutes. Typically, more than 90% of chicks reach the sea by 0230 (Gaston 1992).

Since 1990, a portion of departing chicks at East Limestone Island has been trapped en route to the sea using plastic fences ("funnels"), which intercept them and guide them to a trapping station close to the shore (Figure 1), where the time of arrival is recorded and chicks are weighed and banded (Gaston and Descamps 2011). Trapping was carried out between 2230 and 0230 nightly from 7 May until, after the end of May, no chicks were trapped on two nights in succession. Traps were inspected every 15 minutes; thus, times of arrival of chicks at the bottom of the funnels may have been up to 15 minutes earlier than their time of capture. The position of the funnels was kept constant from year to year. Four funnels were positioned to intercept chicks departing from the north shore of the island (funnels 1–4) and records of departing chicks at these sites were obtained from 1990–2006 and in 2010.

After the blowdown in the winter of 2010–2011, fallen trees and branches prevented the deployment of most of the plastic fences for funnels 1–4. However, clearance of debris allowed funnels to be constructed on the site of funnels 3 and 4 in 2012–2014. Funnel mouths were situated in their former position, but the guide fences were shorter and in some cases rerouted, so that the area from which trapped chicks originated was smaller. Instead of inspecting the funnels throughout the night, infrared motion activated cameras (PC900 HyperFire Professional Covert IR, Reconyx Inc., Holmen, Wisconsin, USA) were set up at the mouth of each funnel to photograph chicks passing through a wooden trough, about 12 cm wide at the seaward end of each funnel (Figures 3 and 4). When triggered, the cameras were set to take 10 photographs at 1-sec. intervals. Each image was time- and date-stamped, so that the time of arrival of each chick could be determined from subsequent inspection. In 2012, the cameras were operated for only a few nights as a pilot scheme. In 2013 and 2014, they were operated nightly from 2200 until after dawn, when the media storage cards were collected and downloaded.

The time at which chicks were photographed was compared with the time of capture of chicks in funnels 1–4 in earlier years, using the period 1996–2003, during which the population was relatively stable after a period of population decline caused by Raccoon (*Procyon lotor*) predation (Gaston and Descamps 2011) and before another period of decline after 2003. All times are given in Pacific Daylight Time (GMT + 9 h). Changes in numbers of chicks recorded between 2013 and 2014 at the reconstructed funnels 3 and 4 were compared with numbers recorded at funnels 5 and 6, where the catchment area was less affected by fallen trees (Figure 1).

FIGURE 3. Set up for recording, showing a motion-detector camera, plastic funnel fences, and an exit trough. Photos: Laskeek Bay Conservation Society.

FIGURE 4. Two Ancient Murrelet (*Synthliboramphus antiquus*) chicks making their way through an exit trough. Twigs were placed across the troughs to slow the chicks and ensure that they were captured on camera. Photographs of adult murrelets, deer mice, and deer were also recorded by the cameras. Photos: Laskeek Bay Conservation Society.

Results

The number of chicks trapped at funnels 1–4 during 1996–2003 averaged 327 ± 70 (SD) a year. In 2013, 67 chicks were recorded on camera and judged from the time intervals to be different individuals, but this included 14 chicks passing the cameras after 0230, the cut-off point for observations in earlier years. In 2014, only 13 were recorded on camera (a decrease of 81% from 2013). In contrast, 85 chicks were recorded at funnels 5 and 6 in 2013 and 75 in 2014 (a 12% decrease).

In 2013, chicks were recorded on camera from 0012 to 0519 (mean 0136); 43% of the chicks photographed by 0230 arrived before 0100 and 23% after 0200 (mean 0115). In 2012, only seven images of departing chicks were obtained, with a mean arrival time of 0115 for those photographed before 0230, identical to the timing in 2013. In 2014, 13 chicks were photographed, with a mean arrival time of 0050 and 50% recorded before 0100. Chicks passing through funnels 1–4 in 1996–2003 were captured as early as 2247, with 61% captured before 0100 and only 7% after 0200 (mean 0050). There was little inter-year variation (Figure 5). A comparison of the distribution of captures during 1996–2003 with photographic records during 2013 showed that those in 1996–2003 were significantly earlier (Wilcoxson test, $Z = 2.52$, $P = 0.01$; Figure 6).

Discussion

Arrival of chicks at the bottom of funnels 3 and 4 in 2012 and 2013 was later than in 1996–2003 despite the fact that trapping times in earlier years could have been up to 15 minutes later than arrival times because of the trap inspection interval. Taken together, the results suggest that, after the blowdown, the passage of chicks through the forest to the shore was extended by about 30 minutes compared with earlier conditions.

Several explanations are possible for the chicks' delay in reaching the bottom of the funnels: adults could have been delayed in returning to their burrows if they were disorientated because of changes in the structure of the forest or higher light intensity resulting from elimination of canopy foliage. Alternatively, chicks were impeded during their transit through the forest by debris from the fallen trees. Chicks do not depart from their burrows until the off-duty parent arrives (Gaston 1992), so any delay by the parent will also delay the chicks. However, by chick departure date, the parents would have visited their burrows for inspection and incubation changeovers many times that season and should have known the new landscape intimately. Al-

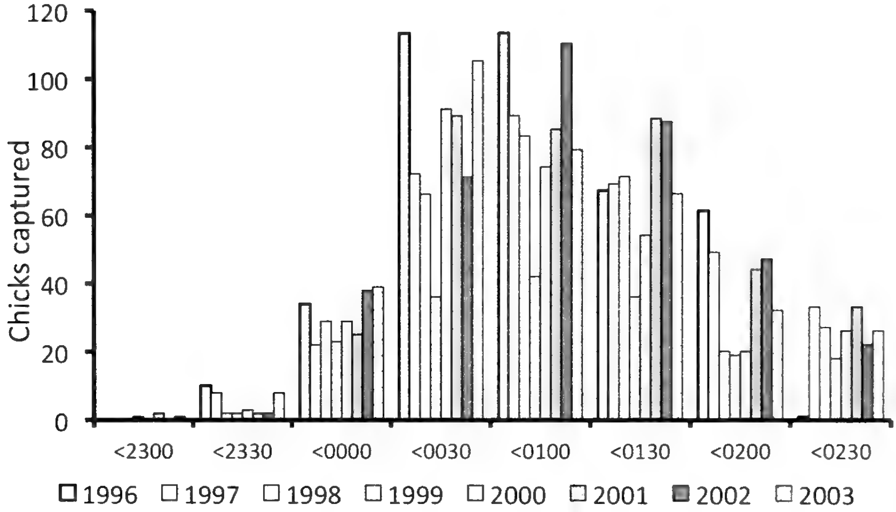

FIGURE 5. Numbers of Ancient Murrelet (*Synthliboramphus antiquus*) chicks captured in funnels 1–4 on East Limestone Island, Haida Gwaii, British Columbia, during 1996–2003 by 30-minute periods.

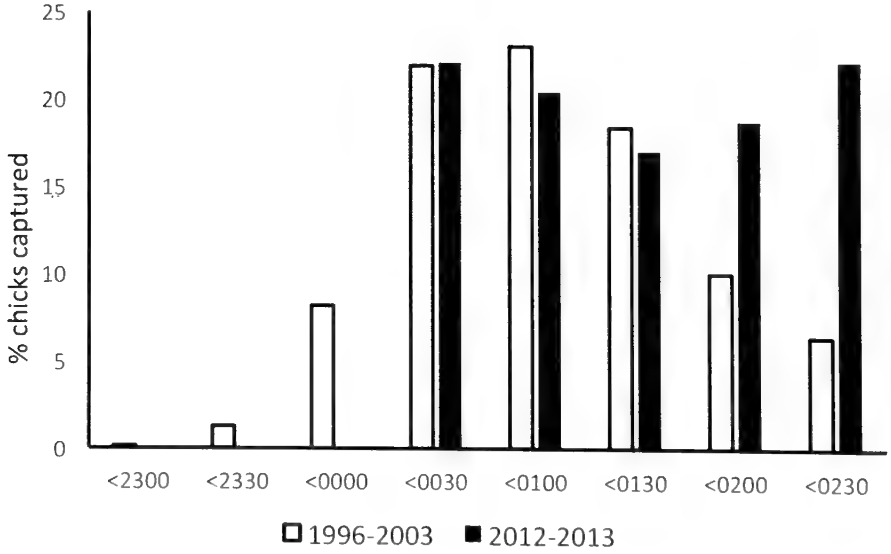

FIGURE 6. Percentage of Ancient Murrelet (*Synthliboramphus antiquus*) chicks captured in 1996–2003 compared with those captured in 2012 and 2013, by 30-minute periods.

though light levels certainly affect the time of arrival of adults, parents that are due to depart that night with chicks are usually among the first to arrive at the colony (Jones *et al.* 1987; Gaston 1992), and, in any case, the darkest time of night occurs at about 0100. With many chicks arriving at the bottom of the funnels after 0200 in 2013, light seems unlikely to have been the main cause of the delay.

Hence, the most likely cause of the delay in the departure of chicks was probably their slower progress on the ground, presumably because of debris from the blowdown. In any case, delays from any cause might have reduced the chance of a successful rendezvous with the parents, especially in the case of chicks arriving after first light (0430). Moreover, some chicks may not have reached the shore on the night of their departure, making eventual reunion with their parents impossible. Delays in the departure process, regardless of whether they caused reproductive failure, may have induced parents to relocate their breeding site away from the area of funnels 1–4, resulting in the steep reduction in the number of departures witnessed in 2014 — a decrease not seen at funnels 5 and 6, which were in areas less affected by the blowdown.

Chicks that were photographed in 2014 arrived at the shore at about the same time as those observed in pre-blowdown years, suggesting that parents of chicks starting close to the shore or otherwise unimpeded in their departure were those that continued to use the area of funnels 1–4, whereas those whose chicks were significantly delayed either refrained from breeding or shifted elsewhere.

As the blowdown area regenerates, vegetation close to the ground will probably become denser, and we expect that numbers of chicks originating from the area of funnels 1–4 will decline further in future, a process unlikely to reverse for several decades. Although East Limestone Island supports only a small colony of Ancient Murrelets, the nearby Reef Island supports several thousand breeding pairs (Gaston 1992), and half of that colony area was affected by similar blowdowns, suggesting that the event may have significant repercussions for the regional population of Ancient Murrelets.

Acknowledgements

We thank all the volunteers and staff who contributed to Ancient Murrelet studies on East Limestone Island since 1990. For comments on the manuscript we thank Keith Moore.

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Received 17 February 2015
Accepted 12 July 2015

Cooperative Hunting of Canada Geese (*Branta canadensis*) by Gray Wolves (*Canis lupus*) in Northern Quebec

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Nichols, Theodore C. 2015. Cooperative hunting of Canada Geese (*Branta canadensis*) by Gray Wolves (*Canis lupus*) in northern Quebec. Canadian Field-Naturalist 129(3): 290–292.

Gray Wolves (*Canis lupus*) are opportunistic predators that feed mainly on ungulates across their range. Incidental to a Canada Goose (*Branta canadensis*) leg banding program in northern Quebec, I observed what appeared to be a predation attempt by three wolves on a flock of 28 Canada Geese at a time when geese were just regaining their flight capability following their annual remige moult (4 August 2003). Although I was able to observe only a short period of this presumed predation attempt, it seemed apparent from the position of the wolves and geese that this was ambushing behaviour described by other authors with other prey species.

Key Words: Gray Wolf; *Canis lupus*; *Branta canadensis*; Canada Goose; cooperative hunting; northern Quebec; predation

Gray Wolves (*Canis lupus*) are flexible and opportunistic predators, but typically prey on large ungulates (Peterson and Ciucci 2003), Caribou (*Rangifer tarandus*) being their primary prey north of the tree line (Kuyt 1972; Stephenson and James 1982). Arctic Hares (*Lepus arcticus*) and Muskoxen (*Ovibos moschatus*) can also be important foods in northern areas where and when Caribou are less abundant (Mech 2005, 2007a). In addition to relative abundance and size, physical vulnerability, defensive behaviour, and environmental conditions influence which prey species are most important in a local area at a particular time (Mech *et al.* 1998). Other prey, such as American Beaver (*Castor canadensis*) and fishes, can also be locally or seasonally important (Voigt *et al.* 1976; Darimont *et al.* 2003).

Although ungulates are Gray Wolves' primary prey, birds are also taken opportunistically. In northern Ontario, Raveling and Lumsden (1977) documented the remains of a Canada Goose that had been killed by a wolf next to a nest. In Nunavut, Wiebe *et al.* (2009) observed wolves feeding on and attempting to take geese (primarily *Chen* spp.), but did not observe any successful predation events. However, their observations occurred during spring when geese would be less vulnerable to wolf predation as they can fly at this time. Wiebe *et al.* (2009) noted that bird remains were found in older wolf scats, suggesting that wolves preyed on birds during the previous summer, presumably while they were flightless during the moult. Mech (1970) cited a letter from J. A. Hagar, reporting evidence of wolves feeding on flightless ducks during August in the James Bay region. Hagar's letter did not state whether ponds were small enough for a lone wolf to flush ducks from them or whether more than a single wolf hunted the ducks cooperatively. Further, Wiebe *et al.* (2009) observed only individual wolves feeding or preying on geese. These authors surmised that wolves might target moulting geese as an adaptive behaviour, because birds are less likely to inflict injury on the predator, compared with large mammals. Here, I report an observation of apparent cooperative hunting of Canada Geese (*Branta canadensis*) by Gray Wolves in northern Quebec.

The study area was characterized by interspersed lichen–heath tundra, lakes, wet sedge meadows, and ponds (Cadieux *et al.* 2005). The dominant vegetation consisted of lichens, Glandular Birch (*Betula glandulosa* Michaux), willows (*Salix* spp.), Mountain Cranberry (*Vaccinium vitis-idaea* L.), Black Crowberry (*Empetrum nigrum* L.), mosses, sedges (*Carex* spp.), and Narrow-leaved Cottongrass (*Eriophorum angustifolium* Honckeny) (Cadieux *et al.* 2005).

On 4 August 2003, while cruising in a helicopter at an altitude of about 50 m above ground level at a ground speed of 150 km/h, I observed what appeared to be Gray Wolves attempting to prey on a flock of Canada Geese. The observation occurred at about 58.66°N, 69.43°W, about 13 km south of Riviére aux Feuilles and about 65 km west of Ungava Bay. The sky was heavily overcast, the temperature was 15°C, and winds were light and variable.

At 0840, I observed a lone wolf wading in an irregularly shaped pond, about 500 m by 150 m in size, toward a flock of 28 adult Canada Geese (Figure 1). The wolf was near the centre of the pond and approaching the flock from the south about 70 m from the nearest goose. The flock of geese was swimming away from the wolf. Based on the water level on the wolf's legs, most of the pond appeared to be less than 1 m deep. While flying over the pond, I detected two additional wolves about 70 m from the north edge of the pond and about 100 m from each other (Figure 1). A second pond lay about 200 m to the north of the pond with the geese and the two hidden wolves were between these ponds. The two wolves on land were facing the flock of geese and were crouched in the cover of hummocks and woody vegetation, such that they appeared to be in a position to attempt to intercept any geese that might try to move to the pond to the north. The terrain between the two ponds appeared to contain enough hummocks and low, woody cover to allow the two wolves to move

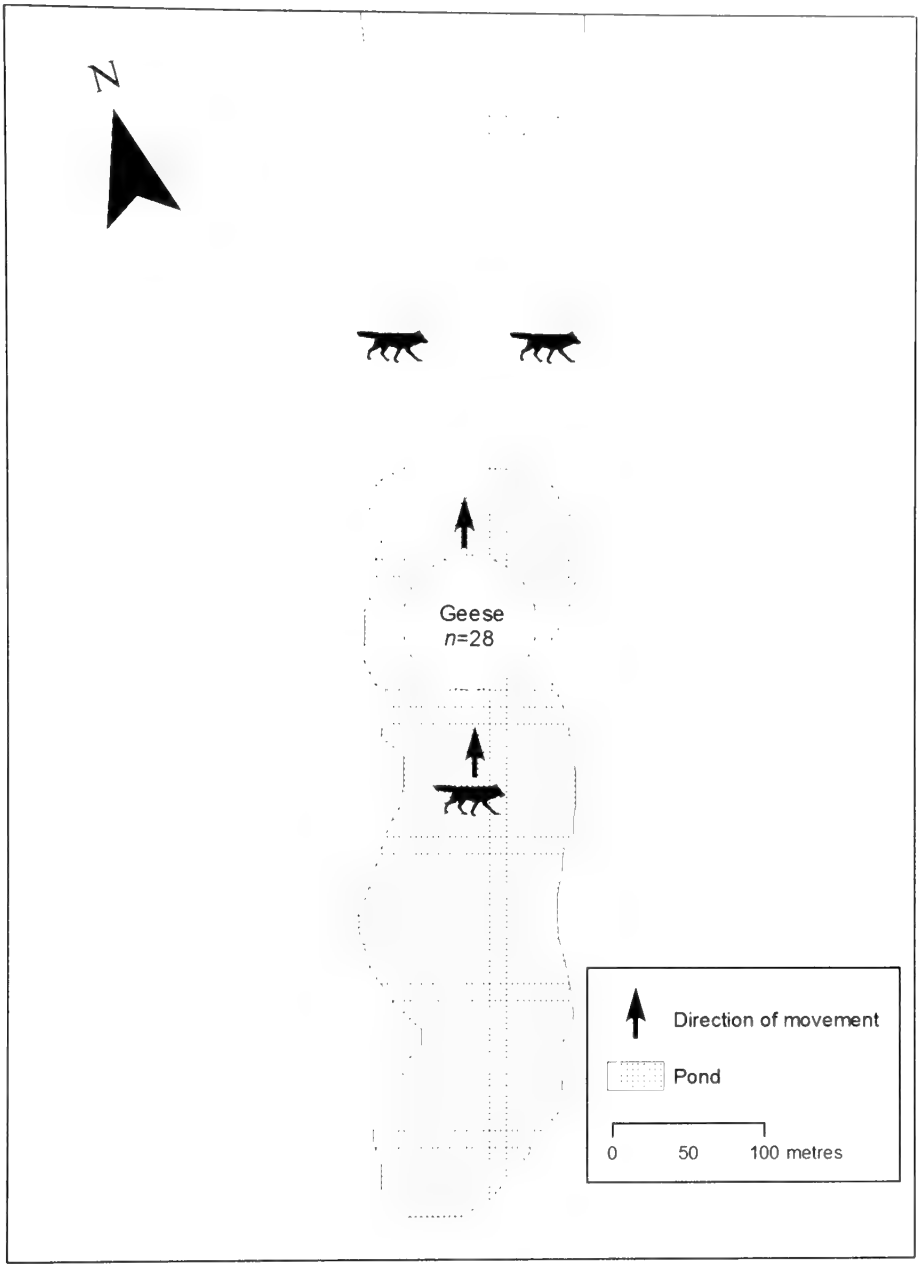

FIGURE 1. Diagram of a predation attempt by three Gray Wolves (*Canis lupus*) on a flock of Canada Geese (*Branta canadensis*) in northern Quebec, Canada, on 4 August 2003. Small arrows show the northward movement of a lone wolf and a flock of 28 Canada Geese toward two wolves crouched under cover of hummocks and woody vegetation.

into their current position without being seen by the geese.

On observing the hidden wolves, I asked the pilot to turn the helicopter and gain altitude so as to view the outcome of the presumed predation attempt. However, as we re-approached the scene from the north, all of the Canada Geese flew off to the south, likely because of the presence of the helicopter.

From 1997 to 2007, when I served on the Atlantic Population Canada Goose banding crew in the Ungava Bay region, we were in the field by helicopter for about 10 days annually between 27 July and 14 August. Our area of coverage each year spanned about 350 km of tundra and boreal forest within a 35-km wide strip along the western and southern coasts of Ungava Bay and major tributaries between Kangirsuk and Kangiqsualujjuaq. We typically spent about five days between our base in Kuujjuaq and Rivière aux Feuilles (90 km), where the incident described above occurred, searching for Canada Geese to band or in transit to banding stations further north. When flying, we spent most of our time searching for Canada Goose brood flocks to band at an altitude of 30 m and a speed of about 60 km/h, i.e., under conditions where Caribou would be readily observed. Although Caribou were common in this area, we never saw herds any larger than 25 individuals during any year; the number of Caribou observed annually averaged about 30 (personal observation). Given the importance of Caribou to Gray Wolf diet in the North (Kuyt 1972; Stephenson and James 1982) and the fact that Caribou were not particularly abundant in this area at this time of year, it is uncertain whether the observation of Canada Goose predation was a relatively common occurrence or an isolated incident.

In a survey described by Peterson and Ciucci (2003), the idea of "strategic cooperation," or wolves hunting as a unit, was not unanimously accepted by wolf biologists. In this same survey, wolf biologists who reported strategic cooperation had observed the prey species to be primarily large ungulates, including Caribou, Horse (*Equus caballus*), White-tailed Deer (*Odocoileus virginianus*), and Moose (*Alces americanus*). Further, Mech (2007b) described wolves using specialized strategies, including ambushing behaviour, when hunting Muskoxen. Regarding non-ungulates, Mech (1995) observed wolves chasing Arctic Hares toward other waiting wolves. I was not able to find any documentation of wolves cooperatively hunting birds.

The date of the observation (4 August) coincided with the time when nonbreeding Atlantic Population Canada Geese first begin to regain flight capability following the moult (personal observation). Therefore, it is plausible that Gray Wolves would still be hunting geese, given that these birds had been flightless for approximately four weeks (Bellrose 1980) before the observation. Although I was only able to observe a short period of this presumed predation attempt, it seemed apparent from the position of the three wolves and the geese, and the timing of the moult, that this was ambushing behaviour used by cooperatively hunting wolves, similar to that described by Mech (2007b).

Acknowledgements

Financial support for the Canada Goose banding program was provided by the Atlantic Flyway Council, the Canadian Wildlife Service, and the United States Fish and Wildlife Service. The Makivik Corporation (Nunavik Research Centre), particularly P. May, provided critical field and logistic support. Nunavik Rotors provided outstanding aerial service during our work. M. Hamer produced Figure 1. D. Person provided thoughtful review and comment.

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Received 12 November 2014
Accepted 1 June 2015

Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

ZOOLOGY

Arthropods of Canadian Grasslands Volumes 3 and 4: Biodiversity and Systematics Parts 1 and 2

Edited by H.A. Cárcamo, and D.J. Giberson. 2014. Biological Survey of Canada Monograph Series Nos. 5 and 6, Box 3443, Station D, Ottawa, ON, Canada, K1P 6P4. Volume 3, 413 pages, 45.95 CAD, Paper; Volume 4, 479 pages, 45.95 CAD, Paper.

The Biological Survey of Canada (BSC) came into being in 1980 and was affiliated with both the Canadian Museum of Nature (CMN) and the Entomological Society of Canada (ESC). While connections with the CMN have lessened, the BSC remains strongly connected with the ESC and secured full not-for-profit status in 2009. The BSC's main stated goal is to "co-ordinate scientific research among specialists on the Canadian Biota." This goal has been met mainly through the production of high-quality publications regarding Canada's insect fauna. These publications have included an electronic journal (*Canadian Journal of Arthropod Identification*) as well as a series of scientific monographs focusing on *Arctic Arthropods*, *Aquatic Insects of Peatlands and Marshes in Canada*, *Spring Habitats and their Faunas*, and *Insects of the Yukon*. The most recent offering of the BSC is the *Arthropods of Canadian Grasslands* book series.

Initially conceived as a three-volume set, the *Arthropods of Canadian Grasslands* series is now concluded with a third and bonus fourth volume. The first volume (*Ecology and Interactions in Grassland Habitats*) was published in 2010. The second volume (*Inhabitants of a Changing Landscape*) followed in 2011. These first two volumes focused on defining the history, geography, and general biological makeup of Canadian grasslands. The final two volumes look specifically at the insect groups that call Canadian grasslands their home.

Following a brief chapter introducing the historical biogeography of the grasslands regions of Canada, *Arthropods of Canadian Grasslands* volume three contains thirteen chapters, each focusing on a different group of arthropods and authored by global entomological experts. Volume four follows with eleven more taxonomically focused chapters. The geographical and taxonomic limits are not strict and vary from chapter to chapter and author to author. For example, there are separate chapters on the moths and butterflies of the Prairies and on moths and butterflies of the Peace River grassland region. Smaller orders of insects (e.g., grasshoppers, stoneflies, and dragonflies) are each lumped into single chapters while the larger orders (e.g., bees and wasps, beetles, and flies) are divided into multiple chapters each focusing on key families. This flexibility is a distinct advantage as it allows for some groups to be explored in great detail. For instance, one of my favourite chapters discusses the 134 species of Robber Flies (Asilidae) found in Western Canadian Grasslands. Focusing on this single family allows the chapter's author (Dr. Rob Cannings) to discuss the geographical and biological differences amongst these species in great detail.

There does not appear to have been a limit on the use of colour images or high-resolution photographs in either volume. Many chapter authors took advantage of this to include numerous, beautiful photos of the insects of interest. Other chapters, perhaps due to a lack of photogenecity on the part of the featured insects, notably lack any photos. Nearly every chapter includes some variation on the comprehensive species list. This checklist approach is of immense value to researchers and excited amateurs alike.

The unique method of publication for this book, combined with the targeted chapter format of both volumes presents the potential reader with a bit of a quandary. While the bound copies of both volumes are handsome indeed, the nearly one hundred dollar combined sticker price may lead the casual reader to reconsider. Those looking to save money, or finding themselves only interested in certain groups of grassland insects, may choose to download individual chapters for free at www.biologicalsurvey.ca/monographs. Whether on a computer screen or printed out at home, this option allows students of targeted groups to access this valuable information at no charge. As two complete volumes, or as a series of individual chapters, *Arthropods of Canadian Grasslands*, volumes three and four, offers a wealth of insect information for those interested in a unique part of the Canadian biological landscape. Hopefully this book series is a sign of the continued valuable input on the part of the BSC.

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Birds and Animals of Australia's Top End: Darwin, Kakadu, Katherine, and Kununurra

By Nick Leseberg, and Iain Campbell. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 272 pages, 27.95 USD, Paper.

This latest book by Leseberg and Campbell is specifically aimed at the species you are likely to see in the coastal region of the Northern Territory. This area they call the Top End and they give introductions to the weather and geology. They describe seven specific habitats and give basic hints on how to watch and where to find wildlife.

The bird (birds are chordate animals too) portion of the book does not follow taxonomic order, but is divided by habitat. There are sections on wetlands and beaches, raptors, forests and open areas. The book covers over 200 species out of Australia's current list of 898 – an amazing quarter of the total in only ten percent of the country's area. The authors do not give a description of each species, nor do they point out identifying features. The text describes something of the bird's biology and where it is most common.

The mammal section focuses on the larger species. For example bats are represented by two large flying foxes and three small species (out of about three dozen species for the area). Similarly the rodent section has photos of three rat species and the text covers only six. As the book's stated purpose is "to cover species likely to be seen by the average wildlife watcher" this focus makes good sense. This year, of the dozen types of "mice" in Ontario, I have seen only three (Deer Mouse, Meadow and Red-backed Voles) and I am actively looking. The authors instead have concentrated on the visible wallabies and other cat-sized marsupials.

The reptile and amphibians are headed by Australia's iconic salty and freshy – the Estuarine and Freshwater Crocodiles. Turtles and an assortment of lizards follow. The snakes include several pythons (the oddly named Children's Python is named for zoologist John Children) and some of the most venomous snakes in the world. The book concludes with 15 cute native frogs and the infamous, introduced Cane Toad.

The book is well illustrated throughout, starting with some clear maps and habitat photos. Each species is illustrated by at least one large photo of the animal in habitat. Many have additional flight photos. The quality of all these images is excellent as the authors selected the best photos from a large pool of photographers. Another feature I really like is the "Where to find" boxes for every species. So if you really want to see a gorgeous Gouldian Finch then try "the road to Edith Falls or the airfield at Timber Creek".

Now I wonder about the book's purpose. There are week-long tours that cover only this region, but most take in other areas as well. For a North American or European why fly to Australia for a short, limited tour as it is impractical. Our choice was two back-to-back, two-week tours that covered eastern and western Australia. I can see Australians buying this book, but it is limited for the foreign visitor.

These authors have produced two other books – the *Wildlife of Australia* (By Iain Campbell and Sam Woods. 2013. Princeton University Press) and a *Field Guide to the Birds of Australia – A Photographic Guide.* (By Iain Campbell, Sam Woods and Nick Leseberg. 2014. Princeton University Press). These are both similar in style and, to an extent, in content. I liked the *Wildlife of Australia* as an addition and back up to a conventional bird guide. The photographic bird guide thrilled me less. This newest book is even more limited. I think I would borrow it, make notes of some key items, but would not carry it with me in my precious baggage allowance.

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Field Guide to the Birds of Australia – A Photographic Guide

By Iain Campbell, Sam Woods, and Nick Leseberg. 2014. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 392 pages, 35.00 USD, Paper.

I often wonder why people write books. It is a huge amount of work with no real promise of reward. The authors state they wanted to produce a simplified book for the novice and visitor. This is a laudable objective as too much information can be confusing. (This is why I recommend the original Peterson bird guides for beginners). The authors have selected 714 species of resident birds and regularly occurring migrants out of the Australian list of 780. They use more than 1,100 photographs as illustrations and provide facing-page text and range maps.

The book begins with a description of the various environmental zones. From a Canadian perspective this is most valuable. The Australian climate, geology and flora are so very different from our lush, green Canada. A portion of finding and identifying birds accurately involves recognising habitat. Canadian visitors to Australia are out of their context, so a good introduction to the eco-zones is a good start.

The species accounts are a little more expansive than Simpson and Day's *Field Guide to the Birds of Australia*, but they give the same identification information. However Campbell *et al.* give more on habitat and suggest the best locations to find the species (useful for a visitor). Also I got a better sense of the chance of seeing a bird.

The photographs are high quality "studio" portraits of both males and females. Seabirds and raptors are often shown in flight. The problem is photographs do not always show the key features. This is exemplified by the photos of White-winged Chough (not a real chough or even a crow). While they are good portraits of this uniform black bird they do not show the large flash of white in the wings. Simpson and Day's art work shows this feature clearly and they also insert a vignette chough on the look-alike currawong page. This is true for several species, such as the Red-backed Kingfisher (the red is just visible behind a branch). Similarly photos give little concept of relative size, something that is important for rails, raptors and ducks. It also means the unusual variations in plumage, such as the odd Fairy Tern that does sometimes have a black tip to its bill, is missed.

The authors say they exclude rare vagrants … as they would confuse the vast majority of users. This makes perfect sense for novices and visitors. So I question the inclusion of Paradise Parrot (no records since the 1920s), the Orange-bellied Parrot (population 30 in remote south-west Tasmania) and the secretive Night Parrot (a wildlife photographer spent 17,000 hours over 15 years to get the first ever photos). They also include other vagrants like some penguins, so they show some inconsistency in applying their rules.

Having read through this guide I developed a series of questions. In particular, why create a new guide when Simpson and Day's *Field Guide to the Birds of Australia* is now in its eighth edition in over 25 years with total sales exceeding over half a million copies? Especially as it is one of the most respected field guides in the birding community. Reviewers comments for Simpson & Day's book include "… *Birds of Australia* is an unrivalled companion", " …top-notch visual presentation, layout, and informational content…" and "… a wonderful piece of work". This classic guide is very tough, entrenched competition.

The section on habitats has maps of the geological and vegetation zones. I became confused when I saw the map for Mulga. It covered areas that were designated as other habitats such as Spinifex Grassland. So I went to Wikipedia and selected the Mulga Lands from the list of "Mulga" options. Wikipedia says Mulga Lands are in inland New South Wales and Queensland and their map disagrees with Campbell. It does appear that in Australia Mulga is an alternative name for the wilderness.

Next I checked Spinifex and found it is a genus of grasses found on the coastal sand dunes of Australia and New Zealand. The inland grasses belong to the genus Triodia (commonly known as spinifex). A map in a scientific paper agrees with Campbell's distribution.

So I moved on to Mallee, a type of eucalypt that has multiple stems on an underground tuber. The map in "Plants of the Mallee Shrublands" from the Australian National Botanic Gardens partially agrees with Campbell's map, but the distribution of Malleefowl is in entire agreement.

I found these inconsistencies puzzling, but not distracting. When the author claims "that this guide almost always follows the International Ornithological Congress (actually the International Ornithologists' Union, formerly International Ornithological Committee) taxonomy (IOC World Bird List 3)" (actually now at 4.4) I was surprised. I had already noted the odd position of the frogmouths and nightjars in the book, the ten to twelfth family in the book, as they are 77th in IOC's list of 241 extant families. Even more strange was the seventh position of Australasian Gannet and 19th for boobies. The Sulidae – Gannets, Boobies – are together and 32nd. I am all for putting birds of a feather together (the falcons with the hawk, the waterbirds – ducks, grebes, loons etc.) in a field guide, but this order make no sense. The authors do split the Osprey into two species – the Eastern or Australian Osprey and the Western Osprey.

The guide covers only mainland Australia and Tasmania, but not the offshore territories. The one star bird on my Aussie list, Common Redpoll, is not included because I saw it on Macquarie Island. Technically Macquarie is part of Australia even though it is over 3,800 km away from the mainland.

So I am not sure how I would make out with this guide in the field. I intend to take it on my next trip to Australasia in 2015 and see how it compares to and supplements Simpson and Day's *Field Guide to the Birds of Australia*.

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A Buzz in the Meadow

By Dave Goulson. 2014. Random House Canada, 320 Front Street West, Suite 1400, Toronto, ON, Canada, M5V 3B6. 266 pages, 18.99 CAD, Paper.

In 2003, the author, a Professor of Biological Sciences at the University of Sussex, UK, purchased an old farm (*Chez Nauche*) along with 13 hectares of meadow in rural France. His intention was to develop a wildlife sanctuary, in particular a haven for bumblebees which have been a focus of his research and conservation efforts for over 20 years.

A Buzz in the Meadow is a diverse collection of stories based on the *Chez Nauche* property that aims first and foremost to inspire readers to a greater appreciation of the World's smaller creatures, especially insects and their relatives, but also including a few other invertebrates and small vertebrates.

The first part of the book (Tales from the Meadow), taking up about half its length, introduces readers to *Chez Nauche* and the meadow, and to the foundations of what Goulson terms 'The Insect Empire', a lay summary of early arthropod evolution and the subsequent success and spread of the Insecta. Later chapters in this first part then follow a similar pattern. An insect or group of insects common at *Chez Nauche* is selected, with some aspect of their biology being described. This then leads to a discussion of some broader fundamental biological question. For example, Chapter 4 (Mating Wheels and Sexual Cannibalism) starts by describing the curious manner in which sperm transfer is achieved in Odonata (dragonflies and damselflies), and the idea that it may have arisen as a means by which the male avoids becoming prey for his larger, perhaps hungry, partner. Goulson then expands this discussion into a more general one on courtship and mating in predatory insects (a male's preference for sex rather than self-sacrifice – at least until he has inseminated the female).

Having laid the groundwork to some of the inhabitants of *Chez Nauche*, in Part II (The Rich Tapestry of Life) Goulson moves on to discuss some aspects of the meadow as an ecosystem, focusing on pollination, a process that illustrates par excellence the myriad interactions among insects and plants and one on which the author has done a significant amount of research.

In the first of the three chapters in this part, Goulson summarises the complex relationship between flower structure and an insect's search for nectar and pollen: is the structure such that it will attract a range of insect species, or is the structure so designed that only a few species are attracted (and are able to effect pollination)? Included in this chapter is a discussion on some relatively new research showing that flowers may not only offer a nutritive reward but also a thermal one, the flowers trapping heat much as in a greenhouse, so that their temperature may be many degrees above ambient. An advantage to the plant is that the higher temperature may volatilise scents that attract potential pollinators, while for the insect visitors, especially those like bumblebees that forage at cool temperatures, the flower provides a place to rest and have a warm drink!

The previous discussion provides a background for Goulson's next chapter (Robbing Rattle) in which he considers the insect-plant interactions in an ancient flower-filled meadow, and how such meadows have for the most part disappeared due to agricultural practices, in particular fertiliser application which enhances growth of grasses that crowd out flowers. This leads nicely into the role of a conspicuous plant of meadows, Yellow Rattle (*Rhinanthus minor*), a parasitic plant whose roots attach to those of grasses, drawing out nutrients for its own use. As a result, the grasses become weakened, allowing meadow flowers to re-establish. Rattle is pollinated by a number of long-tongued bumblebee species whose decline in number can be at least partially attributed to a decrease in the availability of Yellow Rattle. The chapter title, incidentally, refers to the stealing of nectar from the rattle by some bumblebees that cut a hole at the base of the flower to access the nectary rather than entering the flower by the normal route.

The three chapters in Part III (Unravelling the Tapestry) show Goulson's strong conservationist leanings. The first (The Disappearing Bees) is an excellent account of how agricultural practices have led to a decline in numbers of both native bees and honeybees (as well as many butterflies and birds), despite governments pouring large amounts of cash into projects designed to correct the trend. Colony Collapse Disorder and the pros and cons of neonicotinoid insecticides are also discussed. This is followed by a chapter on the implications of conserving small 'islands' of native ecosystem, especially as related to genetic drift and inbreeding. In the book's final chapter, Goulson takes the situation on Easter Island, originally forested and with a rich endemic fauna but now treeless and denuded of most native animals, as reflective of what is happening to biodiversity on a global scale. The author's take-home message appears to be that despite our intelligence and knowledge of what's happening to the environment, we seem unwilling to do much about it. He urges much greater efforts towards conservation of biodiversity – not just thinking about rhinos, snow leopards, polar bears and whales, but also bees, beetles, flies, flowers, and all other small creatures.

Goulson is an excellent writer, enthusiastic and able to explain complex biological concepts in a readily understandable way. He also interposes a number of witty 'asides' to enlighten his discussions. This was an enjoyable book to read, and I thoroughly recommend it to field naturalists both professional and amateur.

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Wolves on the Hunt: The Behavior of Wolves Hunting Wild Prey

By L. David Mech, Douglas W. Smith, and Daniel R. MacNulty. 2015. University of Chicago Press, 1427 East 60th Street, Chicago, IL, USA, 60637. 208 pages, 50.00 USD, Cloth.

To be honest, I was a bit giddy having the opportunity to review *Wolves on the Hunt* given the subject matter and the well known wolf biologists who wrote it. The book is a fascinating account of the hunting behaviour of wolves. Nowhere could the title of a text so simply, yet accurately, reflect its contents. Each chapter is extremely detailed and exhaustive, covering all known wolf prey and how they hunt them. This truly is the capstone to first author Dave Mech's outstanding >55 year career studying wolves, and the painstaking time involved in writing this all-encompassing book on wolf predation with first-hand account descriptions of wolves hunting various prey is a tribute to all three authors. It takes endless hours of dedication and perseverance to make these observations and, led by Mech, the authors' own observations dominate the contents of most chapters.

The book description does a great job of summarizing the document's contents as well as the importance of this tome, in stating, "The interactions between apex predators and their prey are some of the most awesome and meaningful in nature—displays of strength, endurance, and a deep coevolutionary history. And there is perhaps no apex predator more impressive and important in its hunting—or more infamous, more misjudged—than the wolf. Because of wolves' habitat, speed, and general success at evading humans, researchers have faced great obstacles in studying their natural hunting behaviours. The first book to focus explicitly on wolf hunting of wild prey, *Wolves on the Hunt* seeks to fill these gaps in our knowledge and understanding. Combining behavioural data, thousands of hours of original field observations, research in the literature, a wealth of illustrations, and—in the e-book edition and online—video segments from cinematographer Robert K. Landis, the authors create a compelling and complex picture of these hunters. The wolf is indeed an adept killer, able to take down prey much larger than itself. While adapted to hunt primarily hoofed animals, a wolf—or especially a pack of wolves—can kill individuals of just about any species. But even as wolves help drive the underlying rhythms of the ecosystems they inhabit, their evolutionary prowess comes at a cost: wolves spend one-third of their time hunting—the most time consuming of all wolf activities—and success at the hunt only comes through travelling long distances, persisting in the face of regular failure, detecting and taking advantage of deficiencies in the physical condition of individual prey, and through ceaseless trial and error, all while risking injury or death. By describing and analysing the behaviours wolves use to hunt and kill various wild prey—including deer, Moose, Caribou, Elk, Dall Sheep, Mountain Goat, bison, Musk Oxen, Arctic Hare, beavers, and others—*Wolves on the Hunt* provides a revelatory portrait of one of nature's greatest hunters."

Wolves on the Hunt is organized into 10 chapters, including the Introduction, which is not an official chapter but is nonetheless very critical in setting the stage for the rest of the book in countering the perception of the wolf as a 'killing machine'. At first glance, the reader might think that wolves can kill any prey item with ease but we learn that this is the furthest from the case as wolves have been killed by many of their prey, including White-tailed Deer, one of the wolf's smaller, regularly preyed upon food items. Thus, the central problem for wolves on the hunt is to kill without being killed (p. 1). We learn that prey have many anti-predator adaptations including herding, bunching up to protect young, yarding, birth-pulsing (or swamping), spreading out, nomadism, migration, sheer size and strength, long, shaggy hair, thick hides, standing their ground, outright endurance, speed, antler defence, attacking/chasing wolves, reaching steep rugged terrain like cliffs/ledges, and escaping to water (Ch. 1-8). Thus, wolves are adapted to travelling many miles to find vulnerable members of each prey species. Wolf pack hunting size is more a function of the survival of pups and adults than for hunting purposes since the larger the pack, generally the less food obtained per wolf and a lower participation rate by pack members (p. 4). For example, with wolves hunting Elk, success peaks at just four wolves although living in larger packs allows older wolves to participate selectively in hunts (p. 4, 88). In fact, only with the wolves' largest prey, bison, does hunting success increase across larger pack sizes (up to 9-13 members; p. 5, 111, 126). The Introduction concludes with a description of the stages of a wolf hunt (p. 8-9) including search, approach, watch, attack-group, attack-individual, and capture. The attack-individual phase of the hunt is the make-or-break stage as this phase of the hunt either ends in failure or the capture phase.

As we move into the chapters with wolves interacting with individual prey species (Ch. 1-8), the reader will find consistency in presentation where each section begins with an introduction that describes each prey's evolutionary adaptations to avoid predation by wolves, as well as specific wolf adjustments to survive on their mostly ungulate (hoofed animal, Ch. 1-7) diet. These adaptations vary given the species of prey and general habitat conditions but the reader gets the picture of the wolf as a very adaptable, relentless species that is highly intelligent and uses the terrain to its advantage from mountain to desert to tundra habitat. The heart of these chapters are the hunting accounts, with most chapters having ca. 50 reports per species, including for the wolf's smallest regularly documented food source, Arctic Hare (p. 147-155). These detailed observations are intended to "immerse the reader in the wolf's life as this intrepid creature strives to find, catch, and kill its wide variety of prey" (p. xii). And the authors do just that, providing many anecdotal reports of wolves hunting prey that, when taken together, provide an exemplary portrait, and rich data source, of wolves on the hunt. These chapters each finish with a conclusion that nicely summarizes the main findings from wolves interacting with their various prey items. In my opinion, this is the most important and succinct section of each chapter as they provide good reference material for the intrepid student looking for literature citations and quotes from this book, which can be found in abundance. The low success rate per hunt and the persistence of wolves in finding vulnerable individuals, which are usually young, old, and infirm members of each species, to prey upon are probably the most important themes that we take away from the book. And we learn that Elk might be the most perfect wolf prey, being a compromise of speed and strength that wolves seem to take preferentially, where available (p. 63). This section resonated with me as I have often watched wolves interact with and feed on Elk during my many trips to Yellowstone National Park (for more, see *My Yellowstone Experience*). Finally, we learn that deep snow is the ultimate equalizer for wolves and snow conditions are critical in all of the accounts, especially that described for White-tailed Deer, Elk, and bison (Ch. 1, 4, and 6).

The conclusion of the book is relatively short, at just five pages (pg. 159-163), but it provides an excellent summary and context for what the reader has digested in the previous sections. The authors note (p. 159) that the general perception might be that wolves can kill just about anything but modern scientists greatly differ from old-time naturalists and current laypeople in their approaches to gathering information and making conclusions about wolves and their behavior. It has been discovered that once prey survives for 1-2 years, many commonly reach old age at 10-20 years of age, and some prey species are so fit they do not even try to avoid wolves, contrary to the 'ecology of fear' idea (p. 159). This is because wolves have to respond to the risk of injury from dangerous prey (including even deer), so they make trade-offs between acquiring food and safety (p. 160). Therefore, wolves generally are only able to kill calves, fawns, and older members of prey populations along with individuals that are diseased, disabled, or in poor condition (p. 161). Occasionally circumstances change whereby a higher proportion of vulnerable individuals are suddenly available, such as during deep snows, prolonged drought, or a sudden birth pulse of young (p. 162). The net result of wolves selecting prey over eons is that prey gradually gets faster, smarter, and more alert in this age-old evolutionary arms race. These processes have helped shape the fleetness of the deer, the alertness of the Elk, and the aggressiveness of the Moose (p. 163).

One subtle thing that I noticed, which might not be gleaned by even trained ecologists upon reading the book, is the fact that national parks played such a critical, underlying role throughout the book. In fact, Superior National Forest (NF) in Minnesota and some remote areas of Canada and Alaska are about the only major exceptions. Much of the wolf-deer interactions were documented in Superior NF as wolves had been fully protected there (similar to a national park) until very recently, and the area is remote making it difficult for human access. However, without Isle Royale, Yellowstone, and Denali National Parks in the United States, and Wood Buffalo National Park in Canada, much of *Wolves on the Hunt* would be incomplete. There are a few reasons for this: (1) scientists can generally study wildlife with less political interference in national parks than in most areas; (2) wildlife lives mostly undisturbed in these areas making them ideal study sites for researchers; (3) there is more infrastructure conducive to studying predator-prey interactions including departments set up for studying these systems, and money for equipment and researchers' salaries; and (4) the intense public interest in national parks makes them an ideal place where results will be picked up by not only scientific outlets (e.g., journals), but also by newspaper reporters, magazines, books, TV newscasts, and nature documentaries. This often feeds into increased funding, which is typified in Yellowstone where a large percentage of the wolf project is funded by private donors. Being from the Northeast U.S., I am envious of the relative lack of such national parks in this area, as well as the comparable lack of infrastructure, at least as of now, to support such studies (say of Eastern Coyotes/coywolves and White-tailed Deer).

The book is well illustrated with tables and figures summarizing data necessary for each chapter. The pictures (in black and white) were a very nice addition to each chapter, 'bringing the words alive' in seeing hunting wolves and their prey. In addition there was a glossy section of 33 colour pictures. These were exceptional, although oddly they were all repeats from some of the black and white pictures found within each chapter. However, the colour images were shown at such a better resolution that this was not necessarily a bad thing. In addition, I watched the accompanying video-clips after I had read the hardcover. This was a very satisfying way to enjoy the 18 video sequences and relate them to the book that I had just finished. There was 64 min 35 sec (64:35) of predator-prey interactions with the shortest segment being 1:12, the longest 9:19, and the average time 3:35, with all scenes filmed within Yellowstone National Park. The clips, including 14 focused on wolves hunting Elk and four on bison, were unedited so some were very raw showing complete kill sequences (including on bull, calf, and cow Elk) that might make some folks squeamish – yet it totally fits this book. The detail of these videos is unparalleled for wolf predation events, a tribute to film-maker Bob Landis' dedication to his craft. And they provide an excellent context to the hunting accounts found in the text, and even though the videos focus on just two of the wolf's prey (i.e., Elk and bison), the reader gets a definite feel for what it is like for wolves to be on the hunt.

I have a few minor criticisms, which certainly does not distract from all but the closest read. One, I noted quite a few minor typos. Most of these were in the first-hand account observations of wolves hunting various prey items. Being a field researcher myself, I can easily see the challenge of converting field notes to book text. Fortunately, these errors do not affect the overall read. Two, the book is so detailed that it can be very tedious to read from cover-to-cover like I did. The great thing, however, is that the book is simple to understand and is organized and presented in a very straightforward manner where not every single account has to be read in-depth to get the gist of the text. If one chooses to comprehend every account, it will take a long time to read, which again is a tribute to the years of effort put into this book. Three, the Introduction chapter could have a couple of improvements. First, it should simply be labelled as Chapter 1 as I felt that this was a vital chapter setting up the remainder of the book, especially following the authors' concisely written Preface (p. xi-xii). As it stands now, it is not labelled as a chapter, yet Chapter 9 is the Conclusion, which is a perfect complement to what we read about in the Introduction. Secondly, because the Introduction has lots of really good information on wolves and their prey, I thought that it could have been broken into sub-headings which would have better organized the section for the reader. Relatively speaking, however, these are negligible critiques and overall I fully endorse that all biologists and laypeople interested in wolves and their prey to buy this book. It has many pictures making it appropriate for your coffee table, and it is organized such that the reader can decide to browse thru the book and digest the important information, or – when having enough time – choose for an exhaustive, meticulous read and subsequent understanding of just how difficult it is to be a wolf. Perhaps Rolf Peterson best described the book in the Foreword (p. x) stating, "If wolves could read, this might very well be their favourite book".

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OTHER

Behind the Binoculars: Interviews with Acclaimed Birdwatchers

By Mark Avery, and Keith Betton. 2015. Pelagic Publishing, PO Box 725, Exeter, UK, EX1 9QU. 158 pages, 69.99 GBP, Paper.

This book is a collection of interviews by two renowned British birders of themselves and 20 other birders (Chris Packham, Phil Hollom, Stuart Winter, Lee Evans, Steve Gantlett, Mark Cocker, Ian Wallace, Andy Clements, Mike Clarke, Debbie Pain, Keith Betton, Roger Riddington, Ian Newton, Steph Tyler, Mark Avery, Stephen Moss, Alan Davies, Ruth Miller, Rebecca Nason and Robert Gillmor). The authors looked for a diversity of people born between 1930 to 1980. Note there are only three women. My casual observation is that I have seen a lower percentage of women when birding in the UK. In North America it is balanced.

While they tried for diversity the first thing I noticed was all these hot-shot birders started before the age of 10. The older people often said they were loners and many said they were "closet" naturalists as birding was not approved by their peers. While a couple were rudely rebuffed by older birders, a number were fortunate to find mentors who boosted both their skills and their scientific purpose. One sad point arose. If I was to offer a ten year old boy a drive to the woods today I would be in deep trouble. My friend Dennis Rupert and I took out three young boys, with enlightened parents, and all grew to be great teenage birders. This ability to teach, encourage and guide the young is now sadly lost. In a similar vein these folks wandered alone, unsupervised, through woods, along reservoirs and over heaths, on foot or bike. Would parents let their children roam like this today?

Fortunately in 1965 the Royal Society for the Protection of Birds (RSPB) – the UK's premier wildlife organization started the Young Ornithologists Club or YOC to promote and help young naturalists. A lot of the birders in this book became members and benefited greatly from its programs. This helped fill in the loss of the freedoms noted above.

Before reading this book you need to understand the term "twitcher." In North America I have heard these people called "(tick) lister" or "combat birder." These are highly competitive people who try to see as many bird species in a given area or time period as possible (causing the participant to "twitch" in excitement. While all birders list to some extent, this is more akin to an aggressive numbers game. Twitchers do contribute to ornithology by finding rare birds and changes in ranges, but their input is small. While I will make an effort to see a rarity (like the Little Egret in Ottawa, 2015) I am not really a lister. On retirement I found I had not updated my life list for 40 years. However I am not as anti-twitcher as Ian Wallace who concluded it was "sheer nonsense."

A good portion of the interviewees have seriously "twitched" for at least some time, before moving on. The race to find and see rarities has provided some amazing records for the UK bird list. Out of the 598 species of birds on the British list as of 7 February 2015, 288 are marked as rare vagrants – that is almost 50%. Many of the interviewees now question the consumption of resources and wonder if there is a better use of funds (for conservation) than twitching.

I was amazed by the talent these people brought to the UK scene. Many are writers of books, reports and scientific papers. Others are artists or photographers. All have played important roles in national, regional or local societies. Their collective contribution to British environmental cause is enormous.

The oldest person interviewed was Phil Hollom, famous as the co-author of a *Field Guide to the Birds of Britain and Europe* in 1954 (along with Roger Tory Peterson and Guy Mountfort). This became the standard field guide to British and European birds. It is now in its sixth edition. Sadly he died, the last of the renowned trio, in 2014 at the age of 102.

One of the interviewer's questions is who would you like to meet. In my case it would be the artist Robert Gillmor. I have admired his art for years and have copies of his prints, and he comes across as an interesting and thoroughly likeable man. His comments exude a charm that comes from experience, reason and balance. Fittingly the book's cover is a print of "Turnstones" by Gillmor.

The two authors are themselves in the elite of UK birdwatchers and they interview each other. Keith Betton is a trainer and consultant who has held executive positions in British Trust for Ornithology, RSPB and African Bird Club. He has an amazing life list of 7500 (the world record is 9000 +). Dr. Mark Avery is an author and wildlife campaigner who has devoted many years to the RSPB. The authors add their last thoughts which echoed the mental review of most interviewees. It gave me much to think about as I plodded out the muddy paths to census reeling flocks of shorebirds – or is that waders?

For me this was a nostalgic book. I related closely to many of the stories, particularly by the older people. It was a fun book to read and should appeal to all avid birdwatchers. So take it to the cottage and curl up by the fire when the rain is heavy and enjoy.

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The Curious Mister Catesby

By E. Charles Nelson, David J. Elliott, and 23 contributors. 2015. The University of Georgia Press, 320 South Jackson Street, Athens, GA, USA, 30602. 425 pages, 42.95 USD, Cloth.

Charles Nelson and David Elliott have taken full advantage of the thirteen years of work by the Catesby Commemorative Trust, the superb ten-years-in-production documentary produced by Cynthia P. Neal in 2007 (still available online from Georgia Public Broadcasting) and the three Catesby symposia held during November 2012 in three consecutive centres: Washington, DC; Richmond, Virginia; and Charleston, South Carolina. Supplementing these efforts with diligent research of their own, Nelson, Elliot and their fellow contributors have produced a book which fully lives up to their claim that *The Curious Mister Catesby* is "the most comprehensive and accurate book produced to date about Mark Catesby." It also lives up to Cromwell Mortimer's 1749 conclusion in *Philosophic Transactions* that Catesby's eleven fascicles with twenty colour plates each, were back then "the most magnificent work I know of, since the Art of printing has been discover'd."

The first chapter by Charles Nelson is an admirable summation of the life of Catesby. Cynthia Neal writes of "Catesby as a remarkably intelligent man with a genius for observation and recall". Karen Reeds tells of the botanical explorers, including Thomas Harriot, John White, John Gerard, John Tradescant, John Parkinson, John Banister and John Ray, who preceded Catesby. Other important chapters deal with the talented Maria Sibylla Merian, who visited Surinam and impressed Catesby with her artistic and scientific skills; the pirate-scholar William Dampier; John Lawson's travels in Carolina; Catesby's journeys in Virginia, Carolina and the Bahamas; and Catesby's plant collections sent to Oxford and to English gardens. Shepherd Krech III cites Frick and Stearn's opinion that Catesby's "lasting fame" has been due to "his contributions as an ornithologist—he was "years ahead of his time" in his "eyewitness evidence" that "birds of passage" migrated annually. Catesby conjectured that want of food might explain some of these movements. Krech elsewhere in 2014 wrote that Catesby's text "surpasses" Rays's editing of Willoughby's *Ornithology*, the standard work to that time.

Henrietta McBurney provides insight into how Catesby based his final paintings on preliminary sketches. Leslie Overstreet discusses the extreme difficulties faced by Catesby in achieving publication, requiring major financial support from 155 "encouragers." Charles Jarvis tells how Catesby's paintings arrived in perfect time to benefit from Latin nomenclature in Linnaeus' landmark catalogue of plants, *Species Plantarum* in 1753 and his catalogue of zoology, *Systema Naturae*, in 1758. Only 34 of Catesby's new species of plants were type species for Linnaeus' binomial Latin names, many fewer than the over 100 new bird species to receive this permanent recognition.

During his Virginia visit, 22 April 1712 to 1719, with side visits to Jamaica and Bermuda in 1714, Catesby supported himself as a primary collector of botanical specimens for his recipients in Great Britain. On his second visit, he collected and painted specimens for himself with an eye to future publication. He arrived at Charles Town 3 May 1722 and toured South Carolina. He was the first naturalist to visit the Bahamas, arriving on Christmas day, 1725 and staying well into 1726 before he returned permanently to England. In London, he encountered Joseph Goupy, who taught him the skills necessary for the labourious task of printmaking, etching and colouring the plates for his eventual book. By the middle of May 1729, Catesby's first twenty plates, each personally hand-coloured, of his *Natural History of Carolina, Florida and the Bahama Islands*, were ready to present to Her Majesty Queen Caroline and to the Royal Society. Parts 2 and 3 followed in 1730, parts 4 and 5 in 1731 and the final six parts in 1734, 1736, 1737, 1739, 1743 and 1747. Failing in health from this lifetime of labour, having coloured 44,000 plates, Catesby died 23 December 1749, aged 66 years, 9 months.

I have a few minor quibbles. The chronology ceased before it informed me that the Catesby Commemorative Trust borrowed the original Catesby paintings from the Royal Collection in Windsor Castle. In 1768, King George III had purchased the standard Catesby set of 220 coloured plates from a bookseller in three leather-bound volumes. The 1997 public exhibition of some of them at Buckingham Palace and in the United States stimulated an international re-examination of Catesby's artistic and scientific achievements; they were separately mounted and photographed by *Alecto Historical Editions Limited* of Essex, England. I regret also that the project does not explain what was involved in the "digital realization of original etchings" by Lucie Hey and Nigel Frith. Co-author Charles Nelson informs me that Hey and Frith's touched-up details of Catesby paintings were used first by the Trust for the successful and still available one-hour "Vimeo" masterminded about 2007 – and more recently in the printed book.

I also regret that this book has soft-pedalled the achievements and the skills of Mark Catesby, failing to mention Elsa Guerdrum Allen's 1951 naming of Catesby as "the founder of North American ornithology." Rather than "tooting the Catesby horn," the contributors leave each reader to reach his or her own conclusion as to the unprecedented skill of Catesby as a largely self-taught artist and pioneer natural history engraver, well before the invention of lithography in 1798. As a scientist he was often a century ahead of his time, one of the first observers to understand how and why birds migrate.

What factors might have helped Catesby place Charles Town and adjacent South Carolina first for new species named by Linnaeus? As the wealthiest city north of Lima, Peru, available leisure time and ownership of slaves by many who helped Catesby may have been a benefit? Strangely, before the 1770s the North American runner-up locality that sent the second largest number of new bird species for Linnaeus to name was remote Hudson Bay and its fur-traders, via paintings by George Edwards published in 1743-1751, whereas Charles Town medical doctors John Lining and Lionel Chambers were second to Hudson Bay for meteorological observations (Houston *et al.* 2003). What a contrast between affluence and isolation!

The superb illustrations and the quality of the writing and research justify the modest expenditure for this magnificent book. The six pages of Catesby chronology, 33 of end notes, 18 of bibliography, and 12 of scientific names, add greatly to the strength of the collaboration. Books tend to be going out of style, but this landmark book about Catesby's three-centuries-old launching of scientific natural history in North America demonstrates the advantages that the printed text has over digital forms of communication. It therefore belongs in every University library world-wide. I recommend without reservation that naturalists buy it, savour it, treasure it and share it.

Houston, C.S., T. Ball, and **M. Houston.** 2003. The Eighteenth-century Naturalists of Hudson Bay. McGill-Queen's University Press, Montreal, Quebec, Canada.

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Climber's Paradise: Making Canada's Mountain Parks, 1906–1974

By Pearlann Reichwein. 2014. University of Alberta Press, Ring House 2, Edmonton, AB, Canada, T6G 2E1. 402 pages, 28.22 CAD. Cloth.

For those who love the mountains, the Canadian Rockies give a sense of place and wilderness which go on forever and words like majestic, spiritual, grandeur, and limitless are used to describe the feelings which most of us experience on our visits to their challenging slopes. Regrettably they do not go on forever and we always have to come back down the mountain after our brief sojourn into unreachability. For over a century, Canadians and international visitors have been making careful investigations into the reachable parts of the Rockies, spending their summers climbing and winters telling the tales and planning the next year's activities.

This book by historian Pearlann Reichwein is a series of vignettes into the lives and explorations of the Alpine

Club of Canada members from its conception in the flat prairie city of Winnipeg in 1905. The club consisted of many adventurers, professors, clergy and other professionals who wished to climb, explore and conquer the peaks of Canada's Rocky Mountains. The first part of the book deals with the organization of the club, comparing different clubs in existence at the time, English, American and world-recognized organizations which were exploring the Canadian Rockies and taking the recognition of first-time scaling of peaks to their own credit or to the credit of clubs outside Canada. So in a kind of patriotic, competitive ideal and in recognition of how a local club could serve the interests of Canadian mountaineers, outfitters, and adventurers, the Alpine Club of Canada was formed.

At the beginning, the club's interests were solely in climbing peaks previously unrecorded as climbed. Each summer a new camp was established and the surrounding peaks were located and attempted. Later club activities were expanded to conservation of areas for mountaineers and wildlife. As the country opened up with railroads and automobile passable roads from the earlier trails, the members were the first ones to find that their chosen playgrounds were also chosen by other commercial and industrial interests with purely economic gain in mind when marketing the appreciation of the montane wilderness.

Of course, the access to the interior of the Rockies which began the explorations of the club was the right-of-way of the Canadian Pacific Railway, which allowed subsequent development of the Banff area, the Crowsnest Pass areas and the building of hotels and resorts which housed the travelling adventurers and provided access to the jump-off points without travelling for hundreds of kilometers through untracked wilderness. The areas chosen for the yearly camps were very much dependent upon close railway access of supply which could be off-loaded at assembly points for outfitters and their pack animals to complete the final link to the camp.

The hydro-electric power and irrigation potential of the eastern Rockies, specifically in the Waterton Lakes and the Bow River, by development groups were of major concern in the club and much political activity began in the club's discussion, occupying their club publication and annual meetings. The book chronicles the course of the disputed water reserves with the subsequent creation of the Canadian National Parks Association which arose as a response to industrial intervention and preservation disputes. As the well-placed adventurers used their experience and political will, the fruits became a system of national parks with access to many wilderness areas.

The book also chronicles the public discussions of the access into the mountains which the club first designed and maintained. Building of shelter cabins, advocacy for conservation of water, timber and freedom from pollutants began with advocates in the club but ironically became critiques of the club's own practices of setting up the yearly camp and leaving junk on the mountain after the season finished. The clubhouse and climbing shelters also fell victim to other conservation strategies as the parks system evolved. Other events of the club's history are mentioned, like mountain training of soldiers in WWII, where the only experienced group of mountaineers to be recruited as teachers were ACC members, and the club's Centennial Project of scaling 10 peaks named after the 10 provinces, which were significant milestones of the club. Finally, the book discusses the eventual passing of the club's legacy, the mountain parks, to Parks Canada, which had less and less communication with club members and grew to an organization which we now revere as the promoters of conservation and wilderness protection in the same Canadian Rocky Mountain Parks.

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Reclaiming the Don: An Environmental History of Toronto's Don River Valley

By Jennifer L. Bonnell. 2014. University of Toronto Press, 10 St. Mary Street, Suite 700, Toronto, ON, Canada, M4Y 2W8. 316 pages, 65.00 CAD, Cloth.

Rivers are where they come together: the environmental forces and human interventions that shape a landscape. This has been the story of Canada's biggest rivers: the Fraser, Mackenzie, and St. Lawrence, each recapitulating the environmental history of their regions. But as Jennifer Bonnell shows, this is also true for smaller rivers. With headwaters only 38 km from its mouth, and draining only a tiny fraction of southern Ontario, the Don River is nevertheless among the most familiar of rivers, located as it is within Canada's largest city. Her account of its history demonstrates the value of considering a river as we seek to understand how nature and our relationship with it have been transformed through time.

Bonnell explains how the history of the Don is the history of southern Ontario: glacial retreat, Aboriginal settlement (of which few traces survive), European colonization, the growth of industry (including mills and other developments that relied on water, whether for power or process), the increasingly intense use of the river as a receptacle for waste, the apparently unstoppable expansion of Toronto's suburbs, and efforts to conserve selected features of the landscape, including river valleys. The consequence of this history has been the transformation of the watershed environment, including the elimination of streams, wetlands, open land and forests. Until the early 1950s Toronto's ravines were often used as informal waste disposal sites; 47 abandoned landfills have been mapped in the Don watershed alone. Sawmills helped destroy salmon runs: after the 1860s no more would spawn in the Don. This and the later channelization of the lower river, to "improve" its capacity to transport water and silt, epitomized the diverse consequences of transformation of the river ecosystem.

But this is not only a simple story of destruction of a landscape. A new landscape emerged, exhibiting new relations between river, valley, and city. Human activities now dominate, and natural processes have been heavily modified, but these processes nevertheless continue, and often resist control – a persistence experienced through periodic flooding and other events, and through the continuing vitality of natural areas within the watershed. That many of these areas still exist is partly due to the caution imposed on development by floods, especially that of Hurricane Hazel in 1954, but it's also the product of the efforts of conservationists, especially Charles Sauriol. The story of Sauriol's advocacy over several decades for conservation of the Don watershed nicely recapitulates the history of land and water conservation in Ontario – from the Don Valley Conservation Association to the Nature Conservancy of Canada, and from conservation to environmentalism. Conservation in the Don Valley also raises interesting issues about how Canadians define what nature is worth protecting: not just pristine wilderness but habitats influenced by humans, and not just distant places but the backyards of our biggest cities. Bonnell thus performs the valuable service of bringing the history of nature conservation closer to the experience of most Canadians.

She also presents a history that should be of interest beyond the boundaries of the Don watershed. This is a history of not just physical transformation, but of changing ideas about nature: from seeing the river and its landscape as a wilderness to be converted into an orderly garden in Europe's image, or as a problem to be engineered into a convenient transportation conduit, or, most recently, a place worth restoring.

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Saving Global Fisheries. Reducing Fishing Capacity to Promote Sustainability

By J. Samuel Barkin, and Elizabeth R. DeSombre. 2013. The Massachusetts Institute of Technology Press, One Rogers Street, Cambridge, MA, USA, 02142-1209. 276 pages, 29.00 USD, Cloth.

The management of ocean fish populations has been of increasing concern as international fishing pressure increases and fish stocks decline. The problem is often exacerbated because some stocks decline and governments subsidize the fishing industry's switch to alternative, initially more common species. In their academic treatise *Saving Global Fisheries*, the authors describe the inherent problems they see with current international fishing agreements and processes, and propose a comprehensive new approach to managing global fisheries. The authors waste little time in putting forward their case, clearly stating the central theme and purpose of this book very early on. Both the title and the introductory paragraph contain a synopsis of the problems as they see it, and the solution. The major challenge was succinctly summarized on the second page as "too many boats, chasing too few fish", and the main solution was presented on the third page as the "need to see fisheries as long-term environmental resources embedded in ecosystems rather than as solutions to short-term domestic employment crises or the embodiment of noble cultural value. We need to stop subsidizing fishers and figure out how to get people out of the industry". This in essence describes the primary focus and intent of the book, with only additional details and rationale to be added. The authors spend the rest of the book explaining in detail the problems with current approaches to the management of ocean fish stocks, and what they see as the solution. Global fisheries are not specifically defined, but refer to oceanic fish stocks traversing the jurisdictional waters of several different countries. The authors do not appear to be referring to freshwater fish stocks at all, although the same case could perhaps be made for fish stocks in large freshwater systems managed by several adjacent jurisdictions.

The authors lay out their case logically, progressively and in considerable, often excessive, detail. They generally build a thoughtful, sequential argument for a broad global regulatory and policy approach to management, rather than the current piecemeal jurisdiction-by-jurisdiction approach. The latter approach tends to simply shift fishing pressure around geographically and by species, especially when supplemented by fishing industry subsidies.

The book is not for the lay reader, with considerable reliance upon economic theory and principles, for example, why an approach based upon Maximum Sustainable Yield can lead to higher levels of fishing pressure than one based upon Maximum Economic Yield. The authors have a solid grasp on economic theory, and apply a great deal of it to this topic. At times the discussion is as much or more about environmental economics as it is about ecological management. In fact, at times the book seems to be directed more to a non-biological audience, with many economic terms remaining undefined while some basic biological terms, such as recruitment, are. The book uses many acronyms and, while confusing at times, they are all helpfully itemized at the beginning of the book. The book is a tough read at times, and somewhat repetitive in the arguments that are being made. Those simply wanting a general overview of the issue and proposed solution would be well served by sticking to the Introduction and the Conclusion – these two chapters summarize the main points without delving into the economic, regulatory and policy complexities.

While the authors make a generally compelling broad case for their thesis, at times they make sweeping generalized statements that are not well supported. Some statements are well supported by scientific studies and reports, while others appear to be unsubstantiated and undocumented. In particular, the success of existing regional fisheries management programs (and their "micro approach to fisheries management") seems to be almost completely disparaged as unsuccessful and unworkable by definition. Even regional fisheries management programs that manage fish stocks based on scientific advice to limit the catch of specific species within specific geo-political limits are seen as ineffectual by design. Where citations are referenced, they are described by footnotes on each page and also included in a full citation list at the back of the book, a useful redundancy.

The authors are adamant in their belief that existing fishing levels are too high, and that this overcapacity needs to be reduced. They believe that regionally managed industrial fishing as currently practised is unsustainable, that existing fisheries should be phased out, and that developing countries not yet exploiting their fisheries should not aspire to make greater use of this "development dead end". The authors propose a bold solution that would require a high degree of international commitment, collaboration and compliance – a global fisheries organization managing a system of individual transferable quotas. The challenges in implementing such a solution are formidable, and the authors do not shy away from identifying the many large hurdles. While it is difficult to see how such a solution can ever be successfully implemented, the authors optimistically close with what they term their core argument – "we should try". In the end they argue that such an international solution is necessary if we are to save global fisheries.

This book is a valuable contribution to the academic discussion on the management of global fisheries, and could be a useful basis for serious discussions on how to better manage them. At the same time, it is neither an easy read nor a book for those with a more general interest in natural history and natural resource management.

TED ARMSTRONG
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Transient Landscapes: Insights on a Changing Planet

By Ellen E.Wohl. 2015. University Press of Colorado, 5589 Arapahoe Avenue, Suite 206C, Boulder, CO, USA, 80303. 248 pages, 34.95 USD, Cloth.

Transient Landscapes is a travelogue for the naturalist. A collection of short essays, each reflecting the genius loci of a place visited over the course of the author's career as a geologist. Ellen Wohl also shares much of her own emotional interpretation of what she sees. At times the essays are poignant commentaries on ecological degradation. In other examples, the writing reflects the amazement experienced by the ecologically-minded of the biological resiliency of nature. Each contribution has an educational component describing geomorphological change processes which is well-written and interesting. Nevertheless, the essays are not just about the forces that shape our landscapes; some focus almost wholly on the animals and plants within these settings and their adaptations for successful survival.

The essays are grouped into four sections based on the author's own identification of the prevailing cause for change in that landscape: tectonic edge, interior landscape, seasonal weather and human-induced sources. At times an essay seems to fit less well under one of these particular headers, but since each piece is standalone the overall flow of reading is not affected. However, each essay is unified through its reflection on the meaning of transience in the subject location. Transience encompasses short moments to the great stretches of geological time. The author reminds us that we are in a changing landscape no matter what we as individuals can perceive. Wohl does question if perhaps we must come to terms with this transience for our own emotional survival as naturalists in the face of large-scale landscape change. Nevertheless, she counters this philosophical argument repeatedly in her writing when she shares the pain of losing a piece of nature known to her. Those who can be emotionally attached to a place or the life within it will always be affected by its loss.

Several essays take place in the Arctic, often derided for being a composite of barren, empty places by those not able to see beyond into their resilient complexity. Wohl shares stories from her travels here to explain how we can create new emotional linkages with unfamiliar places. She strives to show the value of these places which are most at risk by shifting climate patterns.

Each essay contains a reason for Wohl's being at that place alongside her personal observations while there. This provides a human element in what could otherwise be solely poetic descriptions. Most pieces involve some sort of progression through the landscape, whether it is Wohl heading along a trajectory or through the tracing of change over geological time. Lastly, each essay shares a piece of geomorphology explained in plain terms. This educational aspect of the book is one of its strongest selling points since the reader can learn how landscapes are formed while still enjoying an accessible story.

The sites visited range across the globe but are predominantly based in North America. A map after the introduction shows the sites in relation to the tectonic plates but does not identify the locations explicitly. Some essays are illustrated by black and white photos which help to envision the location, but ultimately the print quality is poor so the landscapes are not done justice. There is loss of depth due to poor contrast. The print font size is also small which makes for challenging reading. Each essay is accompanied by a hand-drawn icon to indicate the predominant change force in that landscape. These are not always clear and there is no legend indicating what each one represents; the reader must refer to a paragraph in the introduction and their own interpretations.

Wohl's book is enjoyable to read for those who appreciate landscapes but are also interested in how they work. Each essay is a short voyage without the need to suffer mosquitoes, damp weather or any discomfort.

TREMAYNE STANTON-KENNEDY

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned
Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros

ZOOLOGY

***Birds and Animals of Australia's Top End: Darwin, Kakadu, Katherine, and Kununurra.** By Nick Leseberg, and Iain Campbell. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–5237. 272 pages, 27.95 USD, Paper.

The Bees in Your Backyard: A Guide to North America's Bees. By Joseph Wilson, and Olivia Messinger Carril. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–523. 288 pages, 29.95 USD, Paper.

Better Birding: Tips, Tools, and Concepts for the Field. By George Armistead, and Brian Sullivan. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–523. 360 pages, 29.95 USD, Paper.

***Birds of Botswana.** By Peter Hancock, and Ingrid Weiersbye. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–523. 400 pages, 29.95 USD, Paper.

A Chorus of Cranes – The Cranes of North America and the World. By Paul A. Johnsgard. 2015. University Press of Colorado, 5589 Arapahoe Avenue, Suite 206C, Boulder, CO, USA, 80303. 208 pages, 29.95 USD, Paper.

***Voices in the Ocean – A Journey into the Wild and Haunting World of Dolphins.** By Susan Casey. 2015. The Knopf Doubleday Group, 1745 Broadway, New York, NY, USA, 10019. 302 pages, 17.38 USD, Cloth.

***A Field Guide to Common Fishes of the Pacific Northwest.** By Andy Lamb, Bernard Hanby, and Phil Edgell. Harbour Publishing, Box 219, Madeira Park, BC, Canada, V0N 2H0. 7.95 CAD, Plasticised pamphlet.

Britain's Mammals: A Field Guide to the Mammals of Britain and Ireland. By Dominic Couzens, Andy Swash, Robert Still, and Jon Dunn. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–523. 320 pages, 29.95 USD, Paper.

***Offshore Sealife Id Guide: East Coast.** By Steve N.G. Howells, and Brian Sullivan. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–523. 64 pages, 14.95 USD, Paper.

***A Field Guide to Seaweeds of the Pacific Northwest.** By Bridgette Clarkson. 2015. Harbour Publishing, Box 219, Madeira Park, BC, Canada, V0N 2H0. 7.95 CAD, Plasticised pamphlet.

Birds of South America: Passerines. By Ber van Perlo. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540–523. 464 pages, 29.95 USD, Paper.

OTHER

***Behind the Binoculars – Interviews with Acclaimed Birdwatchers.** By Mark Avery, and Keith Betton. 2015. Pelagic Publishing Ltd., PO Box 725, Exeter, UK, EX1 9QU. 252 pages, 16.99 GBP, Cloth.

Systems Biology. By Leroy Hood, Sui Huang, Nathan Price, and Ilya Shmulevich. 2015. Roberts and Company Publishers, 7950 E. Prentice Avenue, Suite 206, Greenwood Village, CO, USA, 80111. Page numbers and price not available.

The Chinchaga Firestorm. By Cordy Tymstra. 2015. University of Alberta Press, Ring House 2, Edmonton, AB, Canada, T6G 2E1. 248 pages, 34.95 CAD, Paper.

Conservation Planning: Informed Decisions for a Healthier Planet. By Craig Groves, and Eddie Game. 2015. Roberts and Company Publishers, 7950 E. Prentice Avenue, Suite 206, Greenwood Village, CO, USA, 80111. 432 pages, 45.00 CAD, Paper.

Ecology. By Michael Marchetti, Martha Hoopes, and Julie Lockwood. 2015. Roberts and Company Publishers, 7950 E. Prentice Avenue, Suite 206, Greenwood Village, CO, USA, 80111. Page numbers and price not available.

Environmental Science in the Anthropocene. By Emma Marris, and Virginia Matzek. 2015. Roberts and Company Publishers, 7950 E. Prentice Avenue, Suite 206, Greenwood Village, CO, USA, 80111. Page numbers and price not available.

Evolution: Making Sense of Life – Second Edition. By Carl Zimmer, and Douglas Emlen. 2015. Roberts and Company Publishers, 7950 E. Prentice Avenue, Suite 206, Greenwood Village, CO, USA, 80111. 432 pages, 125.00 CAD, Cloth.

Why Grow Here – Essays on Edmonton's Gardening History. By Kathryn Chase Merrett. 2015. University of Alberta Press, Ring House 2, Edmonton, AB, Canada, T6G 2E1. 352 pages, 34.95 CAD, Paper.

***Transient Landscapes – Insights on a Changing Planet.** By Ellen Wohl. 2015. University Press of Colorado, 5589 Arapahoe Avenue, Suite 206C, Boulder, CO, USA, 80303. 248 pages, 34.95 USD, Cloth.

Two Houses of Oikos – Essays from the Environmental Age. By James A. Schaefer. 2015. Moon Willow Press, 214–4451 Albert Street, Burnaby, BC, Canada, V5C 2G4. 164 pages, 16.95 CAD, Paper.

News and Comment

Upcoming Meetings and Workshops

Raptor Research Foundation Conference

The 2015 Raptor Research Foundation Conference, hosted by the Golden Gate Raptor Observatory, to be held 4–8 November 2015 at the Doubletree Hotel, Sacramento, California. This conference celebrates the 50th anniversary of the ground-breaking Madison Peregrine Falcon symposium and 30 years of raptor migration monitoring in the Marin Headlands. Registration is currently open. More information is available at http://www.raptorresearchfoundation.org/conferences/current-conference.

Société d'entomologie du Québec and the Entomological Society of Canada Meeting

The 2015 Joint Annual Meeting to be held 8–11 November 2015 at the Marriott Château Champlain, Montréal, Québec. The theme of the conference is: 'Entomology in the Anthropocene'. Registration is currently open. More information is available at http://www.seq.qc.ca/activites/reunions/SEQ-ESC_2015/index_eng.asp.

Entomology 2015

Entomology 2015 to be held 15–18 November 2015 at the Minneapolis Convention Center, Minneapolis, Minnesota. Entomology 2015 combines the annual meetings of the Entomological Society of America, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. The theme of the conference is: 'Synergy in Science: Partnering for Solutions'. Registration is currently open. More information is available at http://www.entsoc.org/entomology2015.

The Society for Integrative and Comparative Biology Annual Meeting

The Society for Integrative and Comparative Biology Annual Meeting to be held 3–7 January 2016 at the Oregon Convention Center, Portland, Oregon. Registration is currently open. More information is available at http://www.sicb.org/meetings/2016/index.php.

The Northeastern Plant Health and Pest Conference

The Northeastern Plant Health and Pest Conference to be held 4–8 January 2016 at the Sheraton Society Hill Hotel, Philadelphia, Pennsylvania. This is the joint meeting of the Eastern Branch of the Entomological Society of America, Northeastern Weed Science Society, Northeast Division of the American Phytopathological Society, Northeastern American Society of Agronomy, and Northeastern Branch of the American Society for Horticultural Sciences. More information is available at https://www.agronomy.org/membership/branches/northeastern.

Canadian Conference for Fisheries Research/Conférence canadienne pour la recherche sur les pêches

The Canadian Conference for Fisheries Research to be held 8–10 January 2016 at the Sheraton Hotel, St. John's, Newfoundland. More information is available at http://www1.uwindsor.ca/glier/ccffr/.

Science, Practice and Art of Restoring Native Ecosystems Conference

The annual Science, Practice and Art of Restoring Native Ecosystems Conference, hosted by The Stewardship Network, to be held 15–16 January 2016 at the Kellogg Center, East Lansing, Michigan. Registration is currently open. More information is available at https://www.stewardshipnetwork.org/2016-stewardship-network-conference.

International Conference on Biodiversity and Sustainable Energy Development

The 18th International Conference on Biodiversity and Sustainable Energy Development, to be held 18–19 January 2016 at the Hilton San Diego Resort and Spa, San Diego, California. Registration is currently open. More information is available at https://www.waset.org/conference/2016/01/san-diego/ICBSED.

Midwest Fish and Wildlife Conference

The 76th Midwest Fish and Wildlife Conference to be held 24–27 January 2016 at the Amway Grand Plaza Hotel, Grand Rapids, Michigan. More information is available at http://www.midwestfw.org/index.html.

Society for Range Management Annual Meeting, Technical Training and Trade Show

The Society for Range Management Annual Meeting, Technical Training and Trade Show to be held 31 January–4 February 2016 in Corpus Christi, Texas. More information is available at http://www.rangelands.org/events/.

Erratum The Canadian Field-Naturalist 129(2)

Erratum, Nicholson, Rennie and Mills, 2015. Apparent extirpation of prey fish communities following the introduction of northern pike (*Esox lucius*). Canadian Field-Naturalist 129(2): 165-173.

There is a justification error in Table 2, page 169. The heading "Introduced Northern Pike" should apply to only lakes 110, 221 and 227. All other lakes listed in Table 2 (190, 269, 383, 152, 151, 658, 176, 695, 70, 265, 222) have naturally occurring (native) populations of Northern Pike. See corrected Table 2, below.

TABLE 2. Relative abundance (A = abundant, M = moderate, R = rare) or intentional introduction (I) of fish communities in lakes smaller than 17 ha containing native or introduced Northern Pike (*Esox lucius*).

Lake characteristics and fish community	Native Northern Pike											Introduced Northern Pike*		
	190†	269†	383†	152‡	151‡	658‡	176‡	695†	70‡	265†	222†	110‡	221†	227†
Surface area, ha	5	5	5	5.3	6.5	8.4	9.7	10	11	13	16	5	7	5
Maximum depth, m	6	6	9	6.1	4.2	13.5	3.6	5	3.5	19	6	13	6	10
Esocids														
Northern Pike (*Esox lucius*)	A	A	R	M	M	A	M	M	M	A	A	I	I	I
Coregonids														
Lake whitefish (*Coregonus clupeaformis*)						M								
Cisco (*Coregonus artedii*)						R								
Catostomids														
White Sucker (*Catostomus commersonii*)		A		M	M	M	M	R	M	A	R	M		
Cyprinids														
Northern Redbelly Dace (*Chrosomus eos*)												M		A
Finescale Dace (*Phoxinus neogaeus*)												A		R
Golden Shiner (*Notemigonus crysoleucas*)	R	R						A						
Blackchin Shiner (*Notropis heterodon*)		R									A			
Blacknose Shiner (*Notropis heterolepis*)	M	A	A			M		A		R				
Spottail Shiner (*Notropis hudsonius*)			A											
Fathead Minnow (*Pimephales promelas*)						R		A		R		M		A
Pearl Dace (*Margariscus margarita*)												A	M	A
Cods														
Burbot (*Lota lota*)						R					R			
Centrarchids														
Rock Bass (*Ambloplites rupestris*)	R													
Pumpkinseed (*Lepomis gibbosus*)	M	R					M	M						
Percids														
Yellow Perch (*Perca flavescens*)	M	A	A	M		A	A	M			A		M	
Walleye (*Sander vitreus*)							M							
Iowa Darter (*Etheostoma exile*)								R		R				
Sculpins														
Slimy Sculpin (*Cottus cognatus*)						R				R		M		

*Relative abundance of fishes is based on data collected before introduction of Northern Pike.
†Reproduced from Beamish *et al.* 1976.
‡Not reported in Beamish *et al.* 1976; generated from surveys conducted using similar methods, 1984–2000.

Minutes of the 136th Annual Business Meeting of the Ottawa Field-Naturalists' Club January 13, 2015

Place and time:	Fletcher Wildlife Garden, Ottawa, Ontario, 7:00 pm
Chairperson:	Henry Steger, First Vice-President of the OFNC

Over 20 attendees spent the first half-hour reviewing the minutes of the previous ABM, the financial statements and the OFNC committees' annual reports for 2013-2014. The meeting was called to order at 7:30 pm.

1. Minutes of the Previous Annual Business Meeting

It was moved by Annie Bélair and seconded by Lynn Ovenden that the minutes of the 135th Annual Business Meeting be accepted as distributed.

Carried

2. Business Arising from the Minutes

Nil.

3. Communications Relating to the Annual Business Meeting

Nil.

4. Treasurer's Report by Ken Young

Copies of the treasurer's annual report for 2014, the financial statements, a summary table of the financial statements, and the 2015 budget were made available to all attendees.

Ken first pointed out that the club's financial health is good. One important factor is the large bequest it received from Violetta Czasak in 2013, which is still being processed; Ken is the executor. He said that the total value will be approximately $985,000. Some of the money will be invested. A committee has also been created to consider proposals to use this money.

Regarding the 2015 budget, he said that it is an important management exercise for the club and that it gives a good idea of what committees are planning to do throughout the upcoming year. He didn't discuss it in too much detail, but pointed out that the budget table is always available with the Board of Directors' meeting minutes which are stored on the OFNC website at http://ofnc.ca/council/minutes.php.

He then proceeded to the financial statements, and drew our attention to the summary table. It clearly showed how the club is organized into a "fund accounting" system. More details are available in the financial statements.

Motion: It was moved by Ken Young and seconded by Ian Whyte that the financial statements be accepted as a fair representation of the financial position of the Club as of September 30, 2014.

Carried

5. Committee Reports

The annual committee reports serve as a record of what the OFNC does throughout the year. They were approved by the Board of Directors at their December 2014 meeting. A copy of the reports was distributed to attendees at the beginning of the meeting.

Moved by Annie Bélair and seconded by Diane Lepage that the reports be accepted as distributed.

Carried

6. Nomination of the Accounting Firm

Moved by Ken Young and seconded by Frank Pope that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending September 30, 2015.

Carried

7. Report of the Nominating Committee A. MacKenzie

Relevant Excerpts from the OFNC Constitution (revised February 2000)

Article 8 – "The Council shall consist of the officers of the Club and up to eighteen additional members, all members of the Club."

Article 12 – "The officers of the Club and other members of the Council shall be elected annually at the Annual Business Meeting. The nomination of sufficient persons for election to the various offices and membership of the Council shall be the responsibility of the Nominating Committee, which shall act in the manner prescribed in the By-Laws.

The Council shall, at the earliest possible date, appoint chairs and members of Standing and ad hoc committees and Editor and Business Managers, as required for club publications."

NOMINATED OFFICERS	OFFICIAL DUTY
Fenja Brodo	President
Henry Steger	1st Vice-President
Eleanor Zurbrigg	2nd Vice-President
Annie Bélair	Recording Secretary
Ken Young	Treasurer

NOMINATED OTHER MEMBERS (in alphabetical order)

Carolyn Callaghan
Barbara Chouinard
Julia Cipriani
Owen Clarkin
Barry Cottam
Diane Kitching
Louis L'Arrivée
Alex MacDonald
Ann MacKenzie
Karen McLachlan Hamilton
Lynn Ovenden
Jeff Saarela
Rémy Poulin

Motion: Moved by Ann MacKenzie and seconded by Henry Steger that this slate of nominees be accepted as members of the Board of Directors of the OFNC for 2015.

Carried

Henry thanked Dan Brunton and Don Hackett who will not be returning to the Board of Directors in 2015; he welcomed Jeff Saarela, now chair of the Publications Committee, who is rejoining the board, and Louis L'Arrivée who is also joining.

8. Review of OFNC Constitution and Bylaws for New Regulations

At last year's Annual Business Meeting, Ann MacKenzie, Chair of the Constitution Committee, gave a presentation on the likely implications to the OFNC of the pending changes to the Ontario Not-for-Profit Corporations Act (ONCA). She had explained that changes were anticipated to our classes of membership, to the Board of Directors and with respect to the notification and voting related to the Annual Business Meeting. It was then expected that a revised constitution would be ready for members approval at the January 2016 Annual Business Meeting.

The Constitution Committee, working with the lawyers, have prepared a draft By-law. It is much longer and considerably more complex than the previous bylaw of the OFNC.

However, it cannot be finalized, nor can the Articles (previously referred to as the Constitution) be written until the Ontario government makes progress on the legislation. We are waiting for the act to be proclaimed (it was passed in 2010) and for the accompanying regulations to be written. The website states that the ONCA is not expected to come into force before 2016. Organizations will then have a three year period to come into compliance. As a result this project is on hold.

Everyone thanked Ann and the Constitution Committee for their efforts and patience.

9. In Remembrance

The OFNC noted with sadness the passing of Jack Gillett on December 27th 2014, at age 96. He had worked as taxonomist/botanist at Agriculture Canada and at the Canadian Museum of Nature, served 2 terms as the treasurer of the OFNC and made many significant contributions to the club.

10. New Business and General Discussion

a. Jeff Saarela suggested that the OFNC could finance local research projects. A fund could be established to support these projects, and a committee could be created to evaluate research proposals. Attendees agreed that this was a good idea; it will, therefore, be discussed by directors at board meetings.

b. Ian Whyte had a success story to share: in September 2014, he wrote an article describing how he found snapping turtle hatchlings on the road by the filtration plant at Mud Lake. Because of the curb along the road, it is extremely difficult for the tiny hatchlings to make it to the lake. This article, along with photos, was posted on the OFNC blog at https://ofnc.wordpress.com/2014/09/12/mud-lake-turtle-rescue/. In the article, he asked everyone who would be in the area to check for trapped hatchlings on the road, and bring them to the edge of the lake. He was really pleased with the result! His article mobilized a lot of people and many hatchlings were saved.

   Lynn Ovenden added that social media is working well for the club and pointed out that the OFNC's Facebook page has over 1000 followers.

c. Henry explained that the OFNC has hired a communications consultant who will prepare a 3-year communication plan for the club, which was much needed. He said that all OFNC members will soon receive a survey and invited everyone present to answer it.

d. Throughout the spring of 2014, the OFNC discussed the possibility of making a financial contribution towards the purchase by the Nature Conservancy of Canada (NCC) of a 30.2 hectare land on the Ottawa River in Renfrew County. This piece of land was described as high conservation priority, considering its exceptional karst landscape, the regionally, provincially and nationally significant species found there, and its amazing underwater cave system (which is part of the largest underwater cave system in Canada).

   A contribution of $200,000 (taken from the Czasak bequest) was made on behalf of the OFNC.

   Dan Brunton announced that the land has now been acquired by the NCC.

11. Adjournment

Moved by David Hobden and seconded by Diane Lepage that the meeting be adjourned at 8:15 pm.

Carried

ANNIE BÉLAIR
Recording Secretary

The Ottawa Field-Naturalists' Club — 2013-2014 Annual Committee Reports

Awards Committee

The Awards Committee manages the process to annually recognize those OFNC members and other qualified persons who, by virtue of their efforts and talents, are deserving of special recognition. In 2014, nominations were received and evaluated (see awards criteria http://www.ofnc.ca/awards.php), three nominations were recommended to the Board of Directors for approval, and biographies were written for publication in the Club's journals and posting on the website. The awards were presented at the annual Awards Night in April. The recipients' names, type of award (in brackets) and rationale for recognition follow below:

- Mark Brenchley (Member of the Year) – For his creative and enthusiastic development of educational and promotional materials and promoting the OFNC at events.
- Karen McLachlan Hamilton (George McGee Service) – For over 12 years of dedicated service as editor of *Trail & Landscape*.
- Angelika Skevington (Mary Stuart Education Award) For sharing her knowledge and wonder of nature with students at Huntley Centennial Public School in Carp, Ontario.

Committee members: Irwin Brodo, Julia Cipriani, Christine Hanrahan, Ann MacKenzie

ELEANOR ZURBRIGG, Chair

Birds Committee

The Birds Committee organized the 2013 Fall Bird Count and with the Club des Ornithologues de l'Outaouais, the 2013 Christmas Bird Count. Both events continue to be very popular. This year's Peregrine Falcon Watch was a success at the Heron Road site but once again the downtown pair did not produce any young. The Bird Records-sub Committee continues to work on a revised checklist of the Birds of Ottawa. The new Ottawa chapter of FLAP (Fatal Light Awareness Program) is in its first season of operation and has affiliation with the Birds Committee.

A very successful conference of the Ontario Field Ornithologists (OFO) was held in Ottawa this fall with members of the Birds Committee being heavily involved. As well as organizing many aspects of the conference the committee members were very active as trip leaders. The committee continues to maintain a number of bird feeders in the Ottawa region.

CHRIS TRAYNOR, Chair

Conservation Committee

Two major activities occurred this year:

1. Gervais Property acquisition for permanent conservation:
   In January 2014, we were alerted to a major conservation possibility: a property for sale along the Ottawa River with special karst geology, including the longest network of underwater caves found in Canada, and northerly examples of significant calcicolous flora. The committee considered the features of the site and identified the Gervais Property near Pembroke as a significant natural history feature worthy of conservation. We recommended that the OFNC participate in its protection, drawing upon recently acquired bequest funds to do so. Following a review of the proposal with the evaluation process identified by a specially-assembled OFNC bequest committee, the OFNC Council approved the donation of $200,000 to the Nature Conservancy of Canada. The property has since been successfully acquired for conservation.
2. Launch of Annual Biothon program:
   This year the committee launched what is intended to become an annual event, a year-long bioinventory ("biothon") of a significant natural area in the Ottawa region. The goals of this project are to acquire a thorough and reliable set of biodiversity data regarding a particular significant natural area and to engage the public into participation in natural history activities. We chose the Constance Bay area for our study site, and the event officially launched on the weekend of August 23–24. Working with the OFNC Events Committee, we have held several outings at the site, and others are planned for Constance Bay before the study period ends in August 2015. We have already collected a large amount of data, with hundreds of species observed.

A number of other projects are in progress or are planned thanks to our members which we will briefly mention. These include:

- turtle roadkill and population study along Roger Stevens Drive in Marlborough Forest, aimed at keeping populations healthy with the construction of fencing if necessary.
- daily turtle hatchling rescue at the Mud Lake along Cassels Street
- new strategies to prevent turtle nest site predation
- monitoring of populations of uncommon or declining native plants and naturalizing non-native species. This long-term project is occurring in the urban area (especially for naturalizing non-native plants) and in rural areas (especially for uncommon native plants), with an aim to build on the foundation of data already available in published reports of our region's flora.

This has been among the most productive periods for active OFNC conservation in some years, and I thank everyone for their hard work conserving our natural heritage.

OWEN CLARKIN, Chair

Education and Publicity Committee

This committee provides information to the community about natural history and the OFNC itself. We meet every two months to plan and advise each other on our various responsibilities. One of our tasks is managing a display of various OFNC and natural history items at monthly meetings. We do lots more. In spring, we judge projects at the Ottawa Regional Science Fair for OFNC's special awards; the winners this year were Aidan Gurung, Shamus McCoy and Emma Kirke. In early summer, we selected two local high school students (Emma Kirke and Emily Pollington) for OFNC to sponsor for Ontario Nature's Youth Summit. We manage OFNC's brand identity and the use of our owl logo, be it on signage, publications, certificates, or a tiny lens-wipe pouch that can clip to your camera or binoculars strap. We take turns bringing an OFNC display to natural history events around the city where we encourage visitors to join the club. The big public events this year were BirdDay, BugDay, Ottawa City Hall's Wildlife

Speaker series, and the Ontario Field Ornithologists conference. This year, we made new travel-ready posters for public events, with updated content about joining OFNC, its publications, Macoun Club and Fletcher Wildlife Garden.

A major accomplishment was Linda Burr's completion of the booklet Larose Forest: A Naturalist's Guide. It is a bilingual update of Christine Hanrahan's 2008 description of the forest and includes complete species lists of birds, mammals, herps, butterflies, odonates and vascular plants.

A year ago, when Sandy Garland (OFNC's webmaster) and Natalie Sopinka joined the committee, we broadened our perspective to include the use of social media in education and publicity. Natalie created an OFNC blog called FieldNotes. She has kept it lively with over 50 reports from several people on monthly meetings, local natural history events and profiles of OFNC members. We enlisted a student volunteer in UOttawa's Community Services Program to prepare blog posts about OFNC events this fall. Natalie and Sandy also turned up OFNC's Twitter feed and maintained a steady stream of event notices to OFNC's burgeoning Facebook Group and the Bulletin Board of ofnc.ca. We started to plan a more modern website for OFNC but realized we first needed more clarity about the club's communication goals and target audiences.

Education & Publicity also tries to find speakers, walk leaders or good advice as requested by local organizations that are planning a nature activity. These requests, 16 this year, come from teachers, seniors' programs, and community and youth groups. Many thanks to the many OFNC members who share their knowledge with others.

LYNN OVENDEN, Chair

Events Committee

The Events Committee coordinated 63 outings, 5 workshops, 10 monthly meetings and the annual awards celebration. The outings and workshops included: amphibians and reptiles (3), birds (32), butterflies and moths (3), other insects (6), plants/trees (9), geology (1), photography (3), general natural history (11).

In addition to bringing back many tried and true events and leaders, several new events were offered. Jon Ruddy initiated a spring hawk migration watch, leading 14 outings over an 8 week period to track the migration of hawks, eagles, falcons and vultures. Owen Clarkin, chair of Conservation, launched a one year biothon for Constance Bay. Eleanor Thompson was willing to host "An April Night in the Wilds" at the Thompson cabin near Calabogie, ON. Unfortunately it was cancelled due to the late spring, cold temperatures and the absence of visible amphibians.

The Club's biannual trip to Pelee was sold out appreciation to Fenja Brodo, Roy John and John Cartwright for their roles in the success of the trip.

Monthly meetings were held in the Museum of Nature until December 2013. The January business meeting was held at the Fletcher Interpretation Centre. In February 2014 the monthly meeting moved to the Neatby Building, thanks to Jeff Skevington. Monthly meetings included talks on birds (2), mammals (1), conservation (1), ecology (2), geology (1), insects (1) and plants (1).

Committee members – Robert Alvo, Holly Bickerton, Hume Douglas, Jakob Mueller, Jeff Skevington and Julia Cipriani (chair) with support from Owen Clarkin, Chair of Conservation.

If you have ideas for events or would like to lead an outing or event, please contact Julia (julia cipriani@sympatico.ca) or other members of the committee.

JULIA CIPRIANI, Committee Member

Finance Committee

The OFNC's financial reporting systems are operating smoothly and efficiently. The OFNC Committees have adopted the budget process to look forward to the immediate future to plan their projects and prioritize items. Special projects are presented to the Board for approval and if approved the item is then included in the year's budget. The financial reports provided by the OFNC Treasurer several times a year are a useful tool for the OFNC.

Over the June to September period, the Finance Committee compiled the budget for the next fiscal period, based on submissions and input from each of the OFNC Committees. The Finance Committee had several discussions concerning the budget and provided the draft budget for circulation to the board at the September 2014 meeting. Further discussions and revisions to the budget were made and the board approved the budget at the October 2014 monthly meeting.

The OFNC continues to benefit from unexpected donations which allow committees to think about special projects that otherwise would not be possible. The board has considered these proposals and a couple have been approved for the coming fiscal period and are included in the budget. The 2014/2015 fiscal budget forecasts a large deficit; however the OFNC has the funds to cover the shortfall.

The Finance Committee continues to promote fiscal responsibility and the OFNC's financial results reflects this operating mandate.

BARBARA CHOUINARD, Chair

Fletcher Wildlife Garden

This is been another busy year for the Fletcher Wildlife Garden. The usual activities have proceeded apace, along with a number of other events and achievements. These are highlighted here; further information may be found in the monthly FWG reports to the Board.

On Feb. 17, the OFNC Board hosted a special meeting of the Board, the FWG management committee (MC) and interested volunteers to discuss the mission and strategic objectives for managing the FWG. These objectives address Outreach & Education, Habitat Improvement, management options for the Control of Invasive Species and Natural History. Participants also made many suggestions regarding volunteers, without whom the FWG could not exist. A document summarizing the discussion and decisions has been formally accepted by both the MC and the Board as a guide for future activities of the FWG.

We had our annual spring potluck on April 7 and the three volunteer groups began their activities in May. In addition to the regular work of maintaining the Backyard Garden, the William Cody Fern Garden was re-established in the east end of the Backyard Garden, with a new flag stone path through it laid down under contract by a local landscaping firm. The Butterfly Meadow group was supported in its efforts by the Invasive Species group, which worked primarily around the perimeter of the BM, creating a series of plots to try different methods of controlling DSV. The annual plant sale, held the first Saturday in June, was the most successful ever.

Both the FWG and the OFNC received awards during Ottawa's first Garden Days event, held at City Hall on June 13. This was but one of a number of events relating to efforts to have a botanical garden established on AAFC lands bordering the FWG on the south. An FWG representative attended a stakeholders meeting in February hosted by the Canadensis Botanical Garden Society; we followed quite closely the Society's Beyond the Edge: Artists' Gardens art installations, held over the summer on the field south of the AAFC's red barn. One of the participants, landscape artist Karl Ciesluk, received permission from the MC to construct two art pieces at the FWG. The recent Garden Symposium provided further information on the status of Canadensis and a partner project, Canada Flora 2017.

The application to Environment Canada for approval of a dredging project to rejuvenate the Amphibian Pond still awaits approval, although we have reason to be cautiously optimistic. A plan for managing the New Woods is beginning to take shape, but we are undecided on what to do with the Old Field. The Ash Woodlot was redefined by the removal by AAFC of 56 ash trees killed by the Emerald Ash Borer.

Volunteers from the Stewardship Rangers, PricewaterhouseCoopers, the Royal Ottawa Hospital and the University of Ottawa helped out in the BM, the BYG and refurbishing the Bill Holland Trail. FWG volunteers led group tours for the Ottawa Horticultural Society, Monarch Teachers Network conference and the Weeds Across Borders conference. Our volunteers took a tour of their own at the Canadian Wildlife Federation's wildlife gardens.

DSV continues to be a serious limiting factor in our efforts to improve and maintain the habitats. Two potentially conflicting initiatives began this year. The AAFC overwintered about 500 larvae of the moth *Hypena opulenta* that feed on the leaves of DSV. The larvae were released at a site on the CEF and hopefully will eventually spread to the FWG. Participants in the February 17 meeting approved the use of glyphosate, a broad-leaf herbicide, in a test area at the FWG for a period of two years. One application of glyphosate by the AAFC killed off the flowers and seed pods of the treated DSV. Efforts to assess the significance of the 'mystery circles' – small areas where DSV does not grow – continue, particularly mapping and monitoring; scientific research has not yet produced any clear results, however.

Communications were again an active area, with the FWG Communications Committee liaising with Nature Canada on its Naturehood program, including establishing the FWG on YardMap, and discussing ways to better inform visitors of what's going on at the FWG. The newsletter continues to be published on a regular basis, our brochures are being revamped and new possibilities explored for the website and social media. The management committee continues to liaise with AAFC through membership on the Central Experimental Farm Advisory Committee – which also closely follows developments relating to the botanical garden – and with the Friends of the Experimental Farm. An FCEF member has joined the MC for a two-year term and an MC attends FCEF team leader meetings in spring and fall. The 5-year lease and collaborative agreements between AAFC and the OFNC regarding the use of the Interpretation Centre and management of FWG lands were renewed in April 2014.

The management committee continued this year with a rotating chair. Despite periodic discussion of this situation, the roles of the chair and the MC require clarification. The MC is also wrestling with such issues as longer-term planning in a purely volunteer environment.

BARRY COTTAM,
Committee representative on Board of Directors

Macoun Club Committee

The Committee put together the month-to-month program for the children by telephone and e-mail. An up-to-date schedule and illustrated record of the weekly activities was maintained on its website (macounfieldclub.ca). On most Saturdays during the school year, Committee members supervised or gave presentations at the indoor meetings (held in the Fletcher Wildlife Garden's interpretation centre) or led field trips (one of them jointly with the OFNC, at the Brewer Park Pond). Most field trips took place either on private properties in Lanark County or at the Club's nature-study area in the National Capital Commission's Greenbelt (Stony Swamp). For about a decade, Macoun Club members and leaders have been attempting to control the initial occurrences of certain invasive species in their study area. In 2014 the Club worked closely with the National Capital Commission there, helping to map Garlic Mustard and Dog-strangling Vine, and continuing to remove them where possible. The Committee produced issue no. 68 of the Club's annual publication, *The Little Bear*, and distributed it to members.

ROBERT E. LEE, Chair

Membership Committee

The distribution of Club membership for 2014 on September 30, 2014 is shown in the table below, with the corresponding numbers for 2013 shown in brackets. The increase in total membership of 48 halts a long-term trend of decreasing membership, Local membership (within 50 km

	CANADIAN		USA		OTHER		TOTAL	
	2014	2013	2014	2013	2014	2013	2014	2013
Individual	354	(324)	10	(12)	0	(0)	364	(336)
Family	296	(288)	0	(0)	1	(1)	297	(289)
Student	20	(11)	0	(0)	0	(0)	20	(11)
Trail & Landscape	1	(2)	0	(0)	0	(0)	1	(2)
Honorary	23	(21)	0	(0)	0	(0)	21	(21)
Life	45	(45)	3	(1)	1	(1)	49	(49)
Other*	25	(23)	0	(1)	1	(1)	26	(24)
TOTAL	764	(714)	13	(15)	3	(3)	780	(732)

*Other represents, for the greatest part, affiliate organizations that receive complimentary copies of the Club's publications.

of Parliament Hill) increased to 658 from 617 in 2014 and 2013, respectively. The number of new members reached 130, the most since the late 1990's. A positive sign for the future of the Club was the increase to 20 in Student Membership, which was initiated in 2012 to encourage interest in natural history among high school and university students.

HENRY STEGER, Chair

Publications Committee

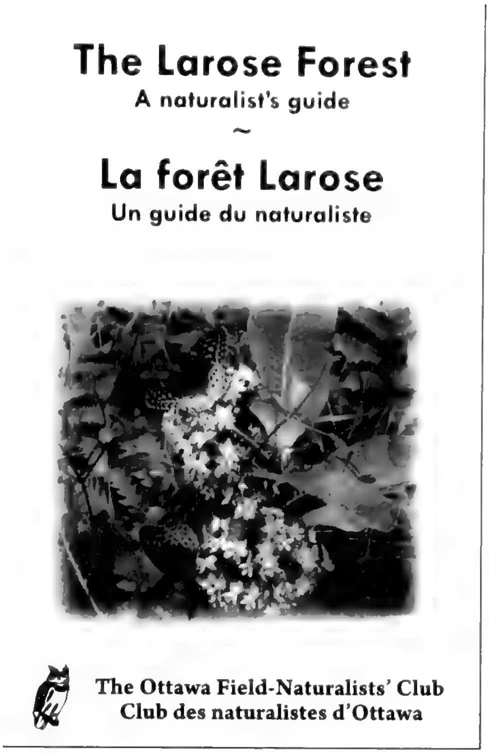
Publications Committee members in 2014 were Carolyn Callaghan, Paul Catling, Jay Fitzsimmons, Tony Gaston, Karen McLachlan Hamilton, William Halliday, David Seburn, Frank Pope, Jeff Saarela and Dan Brunton (Chair). Meetings were held 28 April and 8 October to discuss a wide variety of issues and to provide advice and information to both the OFNC Council and to the editorial teams. As well, a great number of informal communications were conducted electronically amongst committee members on a variety of publication topics, particularly in regards to management and operations of The Canadian Field-Naturalist (CFN).

The CFN continues to be produced on schedule and within the production targets established for the current year (typically, approximately 400 pages/volume). A shortage of copy editing resources has put extra pressure on the already fully-tasked editorial team, however. We are actively in search of more help in that area. Similarly, the operations and management of our subscription base has experienced process difficulties of late. Satisfactorily addressing those difficulties is the primary issue before the committee at present.

CFN Editor-in-Chief Carolyn Callaghan and Assistant Editor Trina Rytwinski and their team produced four issues of the journal this year, 128(1) through 128(4). The increased number of submissions noted with the last two volumes has continued, resulting in an ample supply of quality material in various stages of development for volume 129 issues. Colour images continue to enhance the appearance of more papers than was possible in years past. Unfortunately (for us) Trina Rytwinski is retiring from her position early in the new year to put more focus on other priorities in a busy personal and professional life. She played an especially important role earlier in the year as Acting Editor for 128(1) and 128(2) during Editor-in-Chief Callaghan's winter sabbatical.

We are confident that measures being implemented will eliminate the present CFN operational challenges in the coming year. Accordingly, we look forward to a successful 130th year of publication in 2015.

Four issues of Trail & Landscape were produced by Editor Karen McLachlan Hamilton and her team in the current year. The OFNC web page is becoming an increasingly important vehicle for communications with and amongst OFNC members. Nonetheless, after almost 50 years of publication T&L continues to provide an important newsletter function and to be a significant source of documentation of regional biodiversity and conservation needs.



The Larose Forest
A naturalist's guide
~
La forêt Larose
Un guide du naturaliste

The Ottawa Field-Naturalists' Club
Club des naturalistes d'Ottawa

One Special Publication appeared in the current year, that being "The Larose Forest, a naturalist's Guide", under the editorship and production direction of Linda Burr. Several hundred copies of our first completely bilingual publication are in distribution, particularly in the Prescott-Russell area of the Ottawa Valley where the Larose Forest is situated.

As with most OFNC committees, the demands on personal and professional time often constitute the most significant deterrent to prospective participation. Since a new Publications Committee chair has been confirmed for 2015, arrangements have been made to share participation in OFNC Council and other meetings amongst Committee members. This will lessen the time commitment previously required of the Chair position. My personal thanks to those on and off the Committee who so effectively encouraged and supported the OFNC's unique and nationally significant publications program during my term in that capacity.

DANIEL F. BRUNTON, Chair

Review Engagement Report

To The Members of THE OTTAWA FIELD-NATURALISTS' CLUB

We have reviewed the statement of financial position of The Ottawa Field-Naturalists' Club as at September 30, 2014 and the statements of operations, changes in fund balances and cash flows for the year then ended. Our review was made in accordance with Canadian generally accepted standards for review engagements and accordingly consisted primarily of enquiry, analytical procedures and discussion related to information supplied to us by the club.

A review does not constitute an audit and consequently we do not express an audit opinion on these financial statements.

Based on our review, nothing has come to our attention that causes us to believe that these financial statements are not, in all material respects, in accordance with Canadian accounting standards for not-for-profit organizations.

Welch LLP

CHARTERED ACCOUNTANTS
Licensed Public Accountants

Ottawa, Ontario
December 22, 2014

The Ottawa Field-Naturalists' Club
Statement of Financial Position
September 30, 2014

	2014	2013
ASSETS		
CURRENT ASSETS		
Cash and cash equivalents (note 4)	$ 298,742	$ 55,862
Amounts receivable	16,802	24,380
Prepaid expenses	3,813	633
	319,357	80,875
LONG-TERM INVESTMENTS (note 4)	547,883	537,456
	$ 867,240	$ 618,331
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Accounts payable and accrued liabilities	3,382	$3,582
Deferred revenue	12,953	16,683
	16,335	20,265
FUND BALANCES		
General fund	552,505	317,208
Internally restricted funds	261,337	244,376
Martha Camfield endowment fund	37,063	36,482
	850,905	598,066
	867,240	$618,331

Approved by the Board:

.... President

.... Treasurer

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Statement of Operations and Changes in Fund Balance – General Fund
Year Ended September 30, 2014

	2014	2013
REVENUES		
Membership fees	$ 27,873	$ 28,703
Donations and bequests (note 7)	267,055	27,149
The Canadian Field-Naturalist		
– subscription revenue	23,357	26,153
author charges	27,645	28,234
Fletcher Wildlife Garden		4,395
Pelee Trip	14,937	
Interest income	13,961	13,744
Advertising	150	1,675
Other	1,739	1,828
	$ 376,717	$ 131,881
EXPENSES		
OPERATING:		
Affiliation fees	400	450
Bookkeeping	3,225	4,941
Courier and postage	380	359
Insurance	1,631	1,245
Interest and bank charges	1,246	1,400
Membership	892	1,000
Professional fees	4,130	2,800
Website	2,078	3,500
Fundraising	1,755	–
General and miscellaneous	2,531	3,452
	$ 18,268	$ 19,147
ACTIVITY:		
The Canadian Field-Naturalist	78,758	78,600
Fletcher Wildlife Garden	1,680	7,604
Awards committee	65	534
Soiree – net	138	87
Birds Committee	984	1,010
Donations	5,000	–
Education and publicity	2,612	1,829
Excursions and lectures	1,547	1,953
Macoun Club	241	301
Pelee Trip	12,483	–
Trail and Landscape	7,318	6,986
	110,826	98,904
TOTAL EXPENSES	129,094	118,051
NET REVENUES	247,623	13,830
FUND BALANCE, BEGINNING OF YEAR	317,208	303,378
Inter-fund transfer - to internally restricted funds	(12,326)	
FUND BALANCE, END OF YEAR	$ 552,505	$ 317,208

The Ottawa Field-Naturalists' Club
Statement of Changes in Fund Balance Martha Camfield Endowment Fund
Year Ended September 30, 2014

	2014	2013
Fund Balance, Beginning of Year	$ 36,482	$ 35,900
Interest	581	582
Fund Balance, End of Year	$ 37,063	$ 36,482

Note: In accordance with the endowment agreement, the interest above represents half of the interest generated by the fund and is re-invested in the capital of the fund. The other half of the interest generated by the fund is recognized as interest revenue of the Macoun Fund (see Statement of Operations and Changes in Fund Balances - Internally Restricted Funds) and is made available for the use of the Macoun Field Club.

The Ottawa Field-Naturalists' Club
Statement of Cash Flows
Year Ended September 30, 2014

	2014	2013
Cash Flows from Operating Activities		
Net revenues all funds	$ 252,258	$ 18,517
Adjustments for:		
Amounts receivable	7,578	(8,242)
Investments	54,141	(16,031)
Prepaid expenses	(3,180)	770
Accounts payable and accrued liabilities	(200)	1,299
Deferred revenues	(3,730)	(4,556)
Life memberships	–	(1,240)
	306,867	(9,483)
Cash Flows from Investing Activities		
Purchase of investments	(64,568)	(137,178)
Proceeds from maturity of investments		45,740
	(64,568)	(91,438)
Cash Flows from Financing Activities		
Endowment interest earned	581	582
Increase (Decrease) in Cash and Cash Equivalents	242,880	(100,339)
Cash and Cash Equivalents at Beginning of Year	55,862	156,201
Cash and Cash Equivalents at End of Year	$ 298,742	$ 55,862

Note: Cash equivalents include fixed income investments maturing within three months

The Ottawa Field-Naturalists' Club

Statement of Operations and Changes in Fund Balances – Internally Restricted Funds
Year Ended September 30, 2014

	General Reserve for Contingencies	Fletcher Wildlife Garden Fund	Manning Fund	Seedathon Fund	Ann Hanes Memorial Fund	De Kiriline Lawrence Fund	Macoun Funds	2014 Total	2013 Total
Revenues									
Donations and grants	$	$ 851	$ –	$ 1,061	$ –	$ –	$	$ 1,912	$ 2,655
Fundraising	–	4,916		–		–	–	4,916	
Interest	–	–	3,946	–		–	581	4,527	4,470
	–	5,767	3,946	1,061	–	–	581	11,355	7,125
Expenses									
Habitats	–	4,766		–	–	–	–	4,766	–
Fundraising	–	770	–	–	–	–	–	770	–
Seed	–		–	1,184		–	–	1,184	1,110
Other	–		–			–	–		1,328
		5,536	–	1,184	–	–		6,720	2,438
Net Revenues (Expenses)	–	231	3,946	(123)	–	–	581	4,635	4,687
Fund Balances, Beginning of Year	100,000	–	123,791	808	521	13,384	5,872	244,376	239,689
inter-fund transfer – from General Fund*	–	12,326	–	–	–	–	–	12,326	–
Fund Balances, End of Year	$ 100,000	$ 12,557	$ 127,737**	$ 685	$ 521	$ 13,384	$ 6,453	$ 261,337	$ 244,376

*the inter-fund transfer from the General fund to the Fletcher Wildlife Garden fund was authorized by the Board and is intended to reflect the net revenue from Fletcher Wildlife Garden activities that were reported within the General fund prior to the creation of the Fletcher Wildlife Garden fund

**includes principal of $100,000 plus undistributed income of $27,737

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Notes to the Financial Statements
Year Ended September 30, 2014

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1. Purpose of Organization and Tax Status

The Ottawa Field-Naturalists' Club (the "club") is a volunteer, registered charitable organization incorporated under the Corporations Act of the Province of Ontario. The objectives of the club are to promote the appreciation, preservation, and conservation of Canada's natural heritage and to encourage investigation and dissemination of the results of research in all fields of natural history.

The club's operations are overseen by a Board of Directors (the "board"). Individual activities are undertaken by club members participating in standing committees.

As a registered charity the club is exempt from income taxes by virtue of section 149(1)(f) of the Income Tax Act (Canada).

2. Significant Accounting Policies

Basis of accounting

These financial statements have been prepared in accordance with Canadian accounting standards for not-for-profit organizations.

Revenue recognition

(i) Membership fees are recognized as revenue proportionately over the fiscal year to which they relate. The club's membership year is January 1 to December 31. The portion of membership fees that are received but not yet recognized as revenue are recorded as deferred revenue.

(ii) The club follows the deferral method of accounting for contributions. Restricted contributions are recognized as revenue in the year in which the related expenses are incurred. Unrestricted contributions are recognized as revenue when received or receivable if the amount to be received can be reasonably estimated and collection is reasonably assured. Endowment contributions are recognized as direct increases in net assets. The organization only recognizes revenue from bequests if the will has been probated and a valuation has been received from the executor of the estate and collection can be reasonably assured. Otherwise, revenue from bequests will be recognized as the amounts are received.

(iii) Subscription revenue and author charges are recognized as revenue at the time of release and shipment of the related publication. The liability for the portion of subscription revenue and author charges invoiced in advance of the release and shipment of the related publication is recorded as deferred revenue.

(iv) Trip revenue is recognized at the conclusion of the related field trip. Amounts collected in advance of field trips that have not yet taken place is recorded as deferred revenue.

(v) Interest income comprises interest from cash and cash equivalents and investments. Interest on cash equivalents and investments is recognized over their term using the effective interest method. Interest income derived from the investment of restricted contributions, where the contribution agreement specifies that the investment income is restricted, is accounted for the same manner as the restricted contributions.

(vi) Advertising revenue is recognized in the period in which the advertisement is published.

(vii) Fundraising revenue is included in the statement of operations upon completion of the fundraising event.

(viii) Other revenue includes royalties and the sale of other products and services. Revenue from royalties is recognized in accordance with the related agreement. Revenue from the sale of other products and services is recognized at the time of delivery or when the service has been rendered.

Fund accounting

The Club maintains its accounts in accordance with the principles of fund accounting. Resources are classified for accounting and reporting purposes into funds according to the activity or object specified.

General Fund

The General Fund reports the revenue and expenses relating to general operations and administration activities.

Internally Restricted Funds

(i) General Reserve

The General Reserve for contingencies was established by the Club to fund outstanding operating expenses should the Club discontinue its operations.

(ii) Fletcher Wildlife Garden Fund

The Fletcher Wildlife Garden fund supports the habitat development at the Fletcher Wildlife Garden, with income directed donations and the proceeds for the annual plant sale.

(iii) Manning Fund

The Manning fund was established by a bequest, and the interest generated is used to assist authors to publish articles in the Canadian Field Naturalist.

(iv) Seedathon Fund

The Seedathon fund collects donations from the annual bird sighting event and purchases seed for the Club's bird feeders.

(v) Anne Hanes Memorial Fund

The Anne Hanes Memorial fund was raised in memory of Anne Hanes, the founding editor of Trail and Landscape, and is used to finance the annual winners of the Anne Hanes Natural History Award.

(vi) De Kiriline-Lawrence Fund

The de Kiriline-Lawrence fund was funded by a bequest from the popular author of nature books, and is supplemented by annual donations and used to support conservation efforts.

(vii) Macoun Funds

This comprises the activity of two internally restricted funds, the Martha Camfield Memorial fund and the Macoun Baillie Birdathon fund. The former is used to support special projects of the Macoun Field Club, a youth club. The latter was raised from donations made during the Baillie Birdathons. Its purpose is to support bird research by a Macoun Field Club youth member.

Martha Camfield Endowment Fund

The Martha Camfield endowment fund was established by the family and friends of Martha Camfield to help continue her efforts to have children study, understand, respect and preserve their natural environment. Half of the interest generated by the fund is re-invested in the capital of the fund while the other half of the interest generated is credited to the Martha Camfield Memorial fund and is made available only for the use of the Macoun Field Club. In the Statement of Operations and Changes in Fund Balances — Internally Restricted Funds, the Martha Camfield Memorial fund and the Macoun Baillie Birdathon Fund are consolidated and presented as the Macoun Funds.

Internally Restricted Net Assets

Internally restricted net assets represent the amount approved by the board to be set aside for special purposes. These amounts are not available for unrestricted purposes without the approval of the board.

Financial Instruments

The club initially measures its financial assets and financial liabilities at fair value adjusted by transaction costs in the case where a financial asset or financial liability is subsequently measured at cost or amortized cost. The club measures all of its financial assets and financial liabilities at cost or amortized cost.

Cash and cash equivalents

Cash and cash equivalents include highly liquid investments with maturities of three months or less.

Capital assets

Capital assets are expensed in the year of acquisition.

Donated services

The club is dependent on the voluntary service of many of its members. As there is difficulty in determining the fair value of voluntary services, they are not recognized in these financial statements.

Use of estimates

The preparation of financial statements in conformity with Canadian accounting standards for not-for-profit organizations requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosures of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from these estimates.

Estimates and underlying assumptions are reviewed on an ongoing basis. Revisions to accounting estimates are recognized in the year in which the estimates are revised and in any future years affected.

Significant estimates include those used when accounting for amounts receivable.

3. Financial Instruments

The club is exposed to various risks through its financial instruments. The following analysis provides a measure of the club's risk exposure and concentrations as at September 30, 2014.

Credit risk

The club is exposed to credit risk resulting from the possibility that parties may default on their financial obligations, or if there is a concentration of transactions carried out with the same party, or if there is a concentration of financial obligations which have similar economic characteristics, that could be similarly affected by changes in economic conditions, such that the club could incur a financial loss. The club does not hold directly any collateral as security for financial obligations of counterparties.

The club's maximum exposure to credit risk represents the carrying value of its cash, amounts receivable and investments, totalling $863,427 (2013 – $617,698).

The club's cash is deposited with Canadian financial institutions, as a result management believes the risk of loss on cash to be remote. The cash equivalents and investments consist primarily of government bonds and guaranteed investment certificates of Canadian financial institutions of high credit quality. Possible changes to the credit quality of these securities exposes the club to credit risk. The club manages its exposure to this risk by holding a diversified portfolio with varied maturities. The club reduces its exposure to credit risk on its amounts receivable by reviewing the accounts on a regular basis, following up on outstanding amounts and creating an allowance for doubtful accounts when applicable.

Liquidity risk

Liquidity risk is the risk that the club cannot meet its debts when they become due. Liquidity risk also includes the risk of the club not being able to liquidate assets in a timely manner at a reasonable price.

The club meets its liquidity requirements by monitoring its expected future cash flow requirements and holding a significant amount of assets that can be readily converted into cash.

Market risk

Market risk is the risk that fair value or future cash flows of a financial instrument will fluctuate because of changes in market prices. Market risk is comprised of currency risk, interest rate risk and other price risk.

(i) Currency risk

Currency risk refers to the risk that the fair value of financial instruments or future cash flows associated with the instruments will fluctuate relative to the Canadian dollar due to changes in foreign exchange rates.

Approximately $10,000 (2013 – $18,000) of club's cash and cash equivalents are denominated in U.S. currency. However, the club primarily transacts in Canadian dollars. As a result, management does not believe it is exposed to significant currency risk.

(ii) *Interest rate risk*

Interest rate risk refers to the risk that the fair value of financial instruments or future cash flows associated with those instruments will fluctuate due to changes in market interest rates. The exposure of the club to interest rate risk arises from its interest bearing assets.

The club's cash includes amounts on deposit with Canadian financial institutions that earn interest at market rates. Fluctuations in market rates of interest on cash do not have a significant impact on the club's financial operations.

The club manages the interest rate risk of its cash equivalents and investments by the implementation of prudent investment policies. The club's investments in bonds mature at face value on a staggered basis over the next twelve years. The laddered structure of maturities helps to enhance the average portfolio yield while reducing the sensitivity of the portfolio to the impact of interest rate fluctuations. Effective interest rates to maturity for these securities range from 2.40% to 4.36% (2013 2.40% to 4.36%).

(iii) *Other price risk*

Other price risk refers to the risk that the fair value of financial instruments or future cash flows associates with the instruments will fluctuate because of changes in market prices (other than those arising from currency risk or interest rate risk), whether those changes are caused by factors specific to the individual instrument or its issuer or factors affecting all similar instruments traded in the market.

The club is not exposed to other price risk.

Changes in risk

There have been no changes in the club's risk exposures from the prior year.

4. Cash and Cash Equivalents and Investments

Cash and cash equivalents are comprised of:

	2014		2013
	Market Value	Amortized Cost	Amortized Cost
Cash in accounts – at fair value	$ 228,120	$228,120	$ 55,862
CIBC 4.19% due October 31, 2014	70,740	70,622	–
	$ 298,860	$298,742	$ 55,862

Long-term investments are comprised of:

	2014		2013
	Market Value	Amortized Cost	Amortized Cost
CIBC 4.19% due October 31, 2014	$ –	$	$ 67,782
New Brunswick 4.30% due December 3, 2015	62,085	60,315	60,582
Home Trust GIC – 2.40% due October 12, 2016	34,995	34,995	34,175
Ontario Hydro – 4.01% due November 26, 2016	27,357	27,103	26,058
Ontario 4.07% due December 2, 2017	54,281	50,565	48,588
Ontario – 2.58% due December 2, 2018	65,965	64,483	62,861
British Columbia – 3.74% due March 5, 2019	30,744	28,509	27,481
RBC GIC – 2.51% due September 29, 2019	30,000	30,000	-
Newfoundland – 4.36% due January 7, 2020	46,684	42,375	40,605
British Columbia – 3.26% due August 23, 2021	68,828	65,942	63,860
Nova Scotia Power – 2.80% due February 26, 2022	17,487	17,606	17,126
Manitoba - 2.60% due September 5, 2022	33,699	34,568	–
Hydro Quebec – 3.12% due February 15, 2023	42,376	42,469	41,185
Manitoba – 3.82% due September 5, 2025	51,397	48,953	47,153
	$ 565,898	$547,883	$ 537,456

A portion of the club's cash equivalents and long-term investments totalling $37,063 (2013 – $36,482) is restricted for endowment purposes. The club has not segregated and identified any particular investment as being held for endowment purposes. The club allocates a portion of the total interest generated during the year on all of its investments to the endowment fund based upon the opening endowment fund's balance in comparison to the club's total opening net assets.

5. Capital Assets

No capital assets have been expensed and included in the statements of operations in either the current or preceding fiscal year.

6. Commitments

Life memberships

The club is committed to provide for regular membership benefits to lifetime members. Since it is not practicable to determine the total liability associated with providing these benefits for the rest of the lives of these individuals, the annual costs are expensed as incurred. Lifetime membership are no longer being offered by the club. As of September 30, 2014, there were 49 (2013 – 49) active lifetime members.

Fletcher Wildlife Garden

The Fletcher Wildlife Garden (FWG) is 6.5 hectare property of the Central Experimental Farm in Ottawa, Ontario and is a long-term project of the club. The FWG is managed by a club committee and maintained by club volunteers. The costs associated with maintaining the property are approximately 2,000 hours of voluntary human resources per year, plus regular maintenance and cleaning supplies. The fair value of the contributed human resources are not recognized in these financial statements.

7. Contingent Gain and Subsequent Events

In the prior year, the club became aware that it was the sole beneficiary of an Estate. The entire bequest is unrestricted. One of the club's directors has assumed the role of trustee, and is in the process of settling the Estate. For the year ended September 30, 2014, the Estate transferred cash and investments to the club totalling $261,987. This amount has been recognized as revenue in the club's General fund. Subsequent to the year-end the club received an additional $100,000 from the Estate and the trustee estimates that a further $640,000 will be received by the club by the time the Estate is settled. Amounts received after the year-end will be recognized as revenue by the club upon receipt.

Subsequent to the year-end, the club donated $200,000 to the Nature Conservancy of Canada to assist with the purchase of some ecologically significant land, from the funds received from the Estate.

Book Reviews

News and Comment

Mailing date of the previous issue 129(2): 4 August 2015

THE CANADIAN FIELD-NATURALIST Volume 129, Number 3 2015

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(*continued on inside back cover*)

ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 129, Number 4

October–December 2015

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency the Right Honourable David Johnston, C.C., C.M.M., C.O.M., C.M.
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

2015 Board of Directors

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2, or e-mail: ofnc@ofnc.ca. For information on Club activities, go to www.ofnc.ca

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Website: www.canadianfieldnaturalist.ca/index.php/cfn

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The Manning Fund, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: A blue female American Bullfrog, *Lithobates catesbeianus*, found in the Wallace Bay area, Cumberland County, Nova Scotia, and photographed in natural sunlight. See Gilhen and Russell, pages 395–398 in this issue. Photo: Roger A. Lloyd.

The Canadian Field-Naturalist

Volume 129, Number 4 October–December 2015

Do Ducks and Songbirds Initiate More Nests When the Probability of Survival is Greater?

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Grant, Todd A., and Terry L. Shaffer. 2015. Do ducks and songbirds initiate more nests when the probability of survival is greater? Canadian Field-Naturalist 129(4): 323–330.

Nesting chronology in grassland birds can vary by species, locality, and year. The date a nest is initiated can influence the subsequent probability of its survival in some grassland bird species. Because predation is the most significant cause of nest loss in grassland birds, we examined the relation between timing of nesting and nest survival. Periods of high nest survival that correspond with the peak of nesting activity might reflect long-term adaptations to specific predation pressures commonly recurring during certain periods of the nesting cycle. We evaluated this theory by comparing timing of nesting with date-specific nest survival rates for several duck and passerine species breeding in north-central North Dakota during 1998–2003. Nest survival decreased seasonally with date for five of the seven species we studied. We found little evidence to support consistent relations between timing of nesting, the number of nest initiations, and nest survival for any species we studied, suggesting that factors other than nest predation may better explain nesting chronology for these species. The apparent mismatch between date-specific patterns of nest survival and nest initiation underscores uncertainty about the process of avian nest site selection driven mainly by predation. Although timing of nesting differed among species, the general nesting period was fairly predictable across all years of study, suggesting the potential for research activities or management actions to be timed to take advantage of known periods when nests are active (or inactive). However, our results do not support the notion that biologists can take advantage of periods when many nests are active and survival is also high.

Key Words: Grassland bird; nest survival; nest initiation; passerine; time-specific survival; waterfowl; Gadwall; *Anas strepera*; Mallard; *Anas platyrhynchos*; Blue-winged Teal; *Anas discors*; Northern Shoveler; *Anas clypeata*; Clay-colored Sparrow; *Spizella pallida*; Savannah Sparrow; *Passerculus sandwichensis*); Bobolink; *Dolichonyx oryzivorus*; North Dakota

Introduction

Although nesting chronology can vary by year, often in response to weather, nesting periods may be fairly predictable for a given bird species and locality when considered across many years. For many bird species, nest survival can vary with age of the nest, date in the nesting season, or year. Recent studies conducted in the northern Great Plains show that duck and passerine nest survival is influenced by the date a nest is initiated (Emery *et al.* 2005; Grant *et al.* 2005; Davis *et al.* 2006; Kerns *et al.* 2010; Grant and Shaffer 2012). More specifically, Grant *et al.* (2005) demonstrated that Clay-colored Sparrow (*Spizella pallida*) and Vesper Sparrow (*Pooecetes gramineus*) nests initiated early in the season had higher survival rates than nests initiated later in the season. Furthermore, more nests were initiated during periods when survival also was high (see Figure 2 in Grant *et al.* 2005).

If timing of nesting is adaptive in terms of maximizing breeding success, we would expect that other grassland bird species would also initiate more nests when the probability of survival is greater. Such patterns might reflect long-term adaptations by bird species in response to specific risks of nest predation that recur during certain periods of the nesting cycle. Alternatively, individuals may recognize short-term risks to nest survival, thereby adjusting timing of nesting, perhaps by using environmental cues during the pre-nesting period (e.g., Eichholz and Elmberg 2014).

In this paper, we examine whether more nests are initiated during periods of higher nest survival. We describe patterns of nest initiation among ducks and passerines breeding in the northern mixed-grass prairie of north-central North Dakota and determine the influence of nest age, nest initiation date, and year on nest survival. We then explore patterns of survival in relation to nest initiation date to determine whether the timing of nesting coincides with periods of higher or lower nest survival in a predictable fashion (Grant *et al.* 2005). We focused on seven common species nesting in North Dakota: Gadwall (*Anas strepera*), Mallard (*Anas platyrhynchos*), Blue-winged Teal (*Anas discors*), Northern Shoveler (*Anas clypeata*), Clay-colored Sparrow, Savannah Sparrow (*Passerculus sandwichensis*), and Bobolink (*Dolichonyx oryzivorus*).

Study Area

Our study was conducted on the 23 900 ha J. Clark Salyer National Wildlife Refuge in Bottineau County, North Dakota (about 48°45'N, 100°50'W). The study site is a 450 ha tract of northern mixed-grass prairie, consisting of a needle grass–wheatgrass (*Stipa–Pascopyrum*) association intermingled with two exotic grasses, Kentucky Bluegrass (*Poa pratensis* L.) and Smooth Brome (*Bromus inermis* Leysser), and variably interspersed with short (< 1.0 m) brush dominated by Western Snowberry (*Symphoricarpos occidentalis* Hooker). Since the 1960s, prescribed burning of 100–200 ha blocks of the study area has been carried out every 2–12 years. The area is bordered by cropland adjacent to the refuge and by wetland impoundments of the Souris River. Climate is semi-arid to subhumid continental, with average monthly temperatures ranging from −15°C in January to 20°C in July. During our study, annual precipitation was similar to the long-term average of 43 cm.

Methods

Modeling nest survival: the importance of nest initiation date

From mid-April to late July, 1998–2003, we systematically searched for and monitored nests of grassland birds using the methods of Grant and Shaffer (2012). We used the logistic-exposure method for estimating daily nest survival probabilities using nest initiation date and nest age as time-varying explanatory variables (see Shaffer 2004; Grant *et al.* 2005). Daily nest survival is the probability a nest survives a given day, conditional on it being active at the beginning of that day. A nest survives the interval between visits if at least one egg or nestling is alive on the latter visit or if at least one egg hatched (ducks) or young fledged (passerines) on or before the final visit. For each interval, we assigned midpoint values of nest age and date observed at the beginning of the interval. We used PROC GENMOD (SAS Institute Inc., Cary, North Carolina, USA) to fit logistic exposure models following the procedures of Shaffer (2004).

We used an information-theoretic approach and Akaike's information criterion adjusted for sample size (AIC_c) to identify candidate models that best described the data (i.e., those with the lowest AIC_c score; Burnham and Anderson 2002). We also used the Akaike model weight (w_i), which represents evidence in support of a particular model, given the data and the candidate models considered (Burnham and Anderson 2002: 75). We used the effective sample size, *effn* (Rotella *et al.* 2004) to compute AIC_c (where *effn* = total number of days that nests were known to survive + total number of intervals in which a failure occurred).

Following Grant and Shaffer (2012), we considered six basic models when assessing the relation between daily nest survival and nest age (i.e., number of days from laying of the first egg): (1) constant survival, (2) stage-specific constant survival, (3) survival linearly related to age, (4) stage-specific linear survival, (5) survival non-linearly related to age via a quadratic polynomial function, and (6) survival non-linearly related to age via a cubic polynomial function (only for passerines to allow for differential survival during laying, incubation, or brood-rearing periods). We considered three basic models for describing the relation between daily nest survival and date: (1) constant survival, (2) survival linearly related to date, and (3) survival non-linearly (quadratic polynomial) related to date.

We used combinations of the above to assess 15 and 18 candidate models for each duck and passerine species, respectively, using a multi-step process described in Grant and Shaffer (2012: 321). We first determined whether plot and year effects were important (plot effects were relatively unimportant). When year effects were present, we looked to see if age and date patterns were consistent among years. The outcome of our analyses were species-specific daily nest survival models that accounted for effects of nest age, date in the breeding season, plot, and year; we report only the top two models for each species (Table 1).

Although consideration of time-specific effects was not the focus of this paper and these are described elsewhere (Grant and Shaffer 2012), we needed to account for the influence of nest initiation date on nest survival rates. To investigate the relation between nest initiation date (i.e., the date the first egg was laid) and nest survival, we computed "period survival," as the probability a nest survives the period from nest initiation (on any particular date in the nesting cycle) through hatching of the first egg (ducks) or fledging of the first young (passerines). We calculated period survival as the product of daily survival rates for each day in the nest cycle using available literature, where number of days for egg laying, incubation, and/or brood-rearing is known with some certainty. For example, the nesting cycle for Clay-colored Sparrow consisted of 4 days egg laying, 11 days incubation, and 7 days brood-rearing (22 days total). When daily survival varies with ordinal date, period survival varies with nest initiation date (Shaffer and Thompson 2007). We used equation 2 in Shaffer and Thompson (2007) to estimate period survival in relation to nest initiation date from model-averaged daily survival rates:

$$P_j = S_{j1}\, S_{(j+1)\,2} \cdots S_{(j+k-1)\,k},$$

where P_j is the period survival rate of a nest initiated on day *j* and S_{ji} is daily survival rate on day *j* of an *i*-day-old nest ($i = 1$ to k).

Estimating the number of nests initiated by date

To relate timing of nesting to nest survival, we had to depict the temporal distribution of nests initiated

TABLE 1. Best models ($w_i > 0.10$) that relate daily nest survival to age of the nest, date of the breeding season, and year for ducks and passerines nesting in North Dakota, 1998–2003. K is number of parameters in the model, $\log_e(L)$ is the value of the maximized log-likelihood function, AIC$_c$ is Akaike's information criterion for small samples, ΔAIC$_c$ is the scaled value of AIC$_c$, w_i is the Akaike weight, n is the number of nests, and *effn* is effective sample size.

Model	K	$\text{Log}_e(L)$	ΔAIC$_c$	w_i
Gadwall, *Anas strepera*				
(n = 501, *effn* = 5805)*				
Year, Date^2, Year×Date^2	18	−552.86	0.00	0.51
Year, Plot, Date^2, Year×Date^2	24	−547.43	1.24	0.27
Mallard, *Anas platyrhynchos*				
(n = 314, *effn* = 3033)				
Year, Age^2, Date	9	−304.22	0.00	0.35
Year, Age, Date, Year×Age, Year×Date	18	−295.36	0.46	0.28
Blue-winged Teal, *Anas discors*				
(n = 622, *effn* = 7673)				
Year, Date, Year×Date	12	−667.83	0.00	0.61
Year, Age^2, Date, Year×Age^2, Year×Date	24	−667.51	3.48	0.11
Northern Shoveler, *Anas clypeata*				
(n = 175, *effn* = 2018)				
Year, Stage-const.	7	−160.15	0.00	0.26
Year, Plot, Stage-const.	13	−154.17	0.17	0.24
Clay-colored Sparrow, *Spizella pallida*				
(n = 713, *effn* = 7413)				
Year, Age^3	9	−1095.75	0.00	0.89
Year, Stage-line	11	−1095.84	4.18	0.11
Savannah sparrow, *Passerculus sandwichensis*				
(n = 635, *effn* = 5925)				
Year, Age^3, Date	10	−1107.30	0.00	0.71
Year, Age^3	9	−1109.55	2.49	0.21
Bobolink, *Dolichonyx oryzivorus*				
(n = 142, *effn* = 1207)				
Stage-line	6	−220.48	0.00	0.30
Plot, Stage-line	12	−214.90	1.02	0.18

*AIC$_c$ of best models are Gadwall = 1141.83, Mallard = 626.49, Blue-winged Teal = 1379.70, Northern Shoveler = 334.36, Clay-colored Sparrow = 2209.53, Savannah Sparrow = 234.65, and Bobolink = 453.04.

throughout the breeding season. Patterns of nest initiation constructed from samples of nests can be misleading unless they are adjusted for nests that do not survive long enough to be detected (e.g., nests that are depredated during egg laying but before nest searching, where presence of the female is the primary cue for locating nests). We used the Horvitz-Thompson method (Dinsmore *et al.* 2002; Shaffer and Thompson 2007) to account for such nests (see example in Grant *et al.* 2005: 664).

Relating period survival to number of nests

We used the estimates of period survival and number of nest initiations by date as described above to look for relationships by graphically superimposing period survival rates on the number of expected nest initiations by date in the breeding season (e.g., see Figure 2 in Grant *et al.* 2005). If timing of nesting reflected enhanced nest survival based on long-term predator–prey dynamics, we might expect this relation to be consistent across the 6 years we studied and, therefore, evident using simple graphical comparisons. We recognized that number and timing of nest initiations and nest survival rates might vary among years (related to climate, predators, brood parasites, etc.), and that these variations had potential to complicate such simple graphical comparisons, especially when examined across six nesting seasons. In addition, some species might be able to recognize specific risks to survival occurring before nest initiation. In either case, the relation between timing of nesting and nest survival could vary among years. To account for this sort of variation, we calculated Pearson correlation coefficients relating period survival rates to the number of nest initiations for each species–year combination (42 possible combinations). We did not calculate correlation coefficients in cases where survival was not influenced by nest initiation date.

Results

During 1998–2003, we determined the fates of 3102 nests. For all species, survival varied with age of the nest, initiation date, or year (Table 1). Age and year effects were not the primary focus of our analysis and are discussed elsewhere (Grant and Shaffer 2012). The peak of nesting for all duck species was early May to mid-June. For Gadwall, Mallard, and Blue-winged Teal, but not for Northern Shoveler, nest survival declined with initiation date (Figure 1). Mallard and Northern Shoveler initiated nests earlier in the breeding season than Blue-winged Teal and Gadwall. The timing of peak

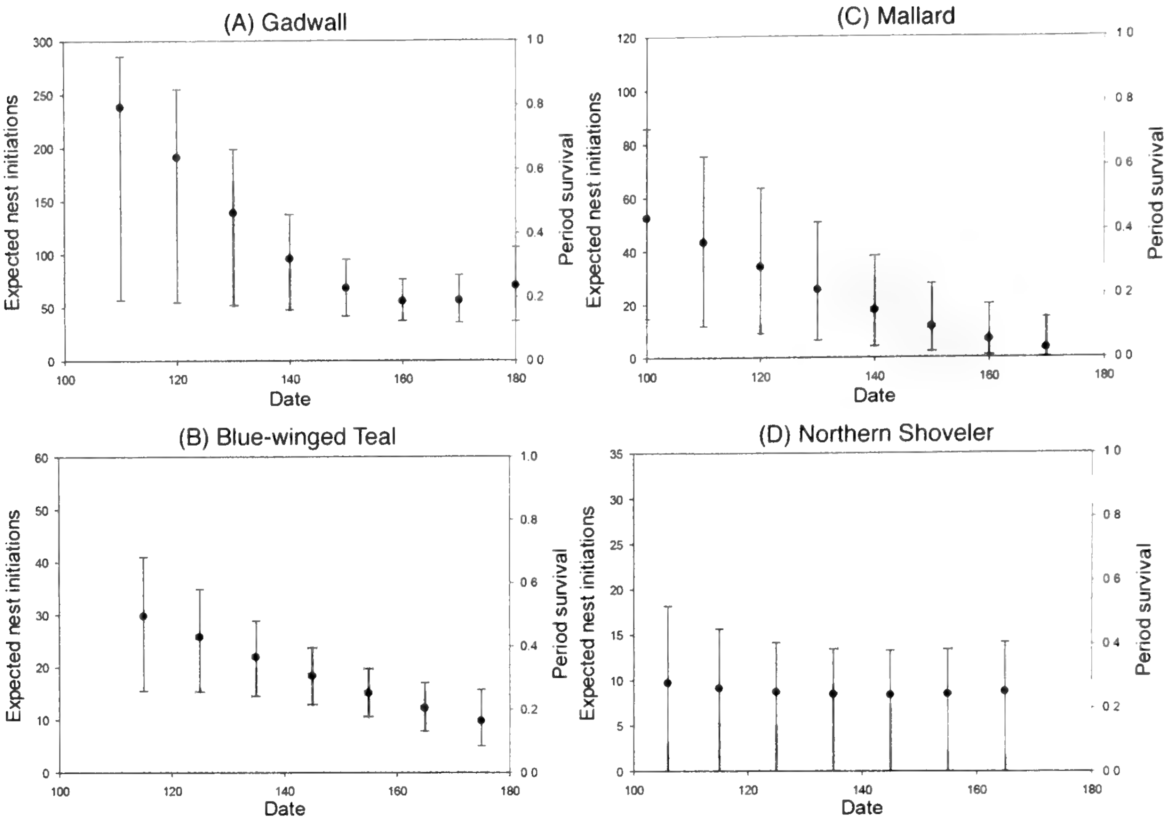

FIGURE 1. Estimated number of nest initiations and period nest survival rates for (A) Gadwall (*Anas strepera*), (B) Blue-winged Teal (*Anas discors*), (C) Mallard (*Anas platyrhynchos*), and (D) Northern Shoveler (*Anas clypeata*) in relation to ordinal date in North Dakota. Solid circles (with 95% confidence intervals) denote the estimated probability of a nest surviving from laying through hatch when initiated on specific dates that span the nesting period (mean 1998–2003). Shaded bars indicate the expected number of nests initiated on each date. Expected initiations account for nests that did not survive long enough to be discovered. Note: The estimated number of Gadwall nests initiated on days 122 and 123 were 875 and 540, respectively.

nest initiations did not correspond to periods of higher or lower survival for Mallard, Blue-winged Teal, or Northern Shoveler (Figure 1), but across all years, Gadwall appeared to initiate more nests during periods when survival also was high (Figure 1). We did not find a single year–species combination for any duck species where number of nest initiations was positively related ($P < 0.05$) to period survival (Table 2). In contrast, seven cases (three for Blue-winged Teal and two each for Mallard and Gadwall) showed a negative association between number of initiations and period survival.

Survival of Clay-colored Sparrow nests did not vary with initiation date, whereas survival of Savannah Spar-

TABLE 2. Pearson correlation coefficients relating period nest survival and number of nest initiations by date for ducks and passerines nesting in North Dakota, 1998–2003. More nests were initiated during periods of higher nest survival in cases where $r > 0$ and $P < 0.05$.

Species (no. nests)	1998	1999	2000	2001	2002	2003
Gadwall, *Anas strepera* (501)	−0.50**	−0.25	−0.04	−0.19	−0.65**	−0.32
Mallard, *Anas platyrhynchos* (314)	−0.50	−0.19	−0.05	−0.51**	−0.51**	−0.16
Blue-winged Teal, *Anas discors* (622)	−0.37*	0.05	−0.47**	0.30	0.31	−0.35*
Northern Shoveler, *Anas clypeata* (175)		Survival did not vary with initiation date				
Clay-colored Sparrow, *Spizella pallida* (713)		Survival did not vary with initiation date				
Savannah Sparrow, *Passerculus sandwichensis* (635)	0.17	0.39**	−0.01	0.22	0.30	0.28
Bobolink, *Dolichonyx oryzivorus* (142)	0.48	0.14	−0.26	0.38	0.74	0.45

*$P < 0.05$.
** $P < 0.01$.

row nests gradually declined from May through July (Figure 2). We found support for two models depicting decreasing nest survival with initiation date for Bobolink (Table 1). Passerines initiated nests 10–20 days later than ducks. Savannah Sparrow and Clay-colored Sparrow initiated nests earlier in the season than Bobolink (Figure 2). Except for Savannah Sparrow, renesting or second brood periods were not readily apparent. The nesting period for Bobolink started later in the spring and ended earlier in summer than that for either Clay-colored Sparrow or Savannah Sparrow. Savannah Sparrow and, perhaps, Bobolink initiated more nests early in the nesting season when survival was also high, although this relation was not compelling (Figure 2). In contrast to ducks, correlations between number of nest initiations and period survival were generally positive for Bobolink and Savannah Sparrow, although only one species–year combination was significant (Table 2).

Discussion

Nesting chronology

In North Dakota, the nest-initiation period for ducks generally spans 42–52 days (Cowardin *et al.* 1985; Lokemoen *et al.* 1990; Krapu 2000) and can be influenced by weather (Hammond and Johnson 1984; Drever and Clark 2007). Renesting among dabbling ducks is common if a first clutch or brood is destroyed; second broods have not been reported. In our study, Mallards initiated first nests in late April and, along with Northern Pintails (*Anas acuta*), are the first ducks to arrive on breeding sites in North Dakota (Hammond and Johnson 1984; Higgins *et al.* 1992). The peak of nest initiation for Mallards was 20 days later than reported for nearly the same location during 1936–1968 (Hammond and Johnson 1984). Dubowy (1996) described Northern Shoveler as among the latest of dabbling duck species to arrive on breeding sites. However, we found the timing and pattern of their nest initiations nearly identical to that of Mallards. Blue-winged Teals arrived slightly later than early-nesting dabbling ducks, but the pattern of their nest initiations was bell shaped, similar to that of Mallards and Northern Shovelers, and peaked about 10 days later than reported by Hammond and Johnson (1984). Gadwall is the latest arriving dabbling duck species in our region (Hammond and Johnson 1984; Lokemoen *et al.* 1990). Although early-season nests were initiated at later dates than other species in our study, Gadwall exhibited a greater proportion of all nests initiated early in the season, gradually declining with date (Figure 1) with the peak date similar to that described for the same location during 1936–1968 (Hammond and Johnson 1984).

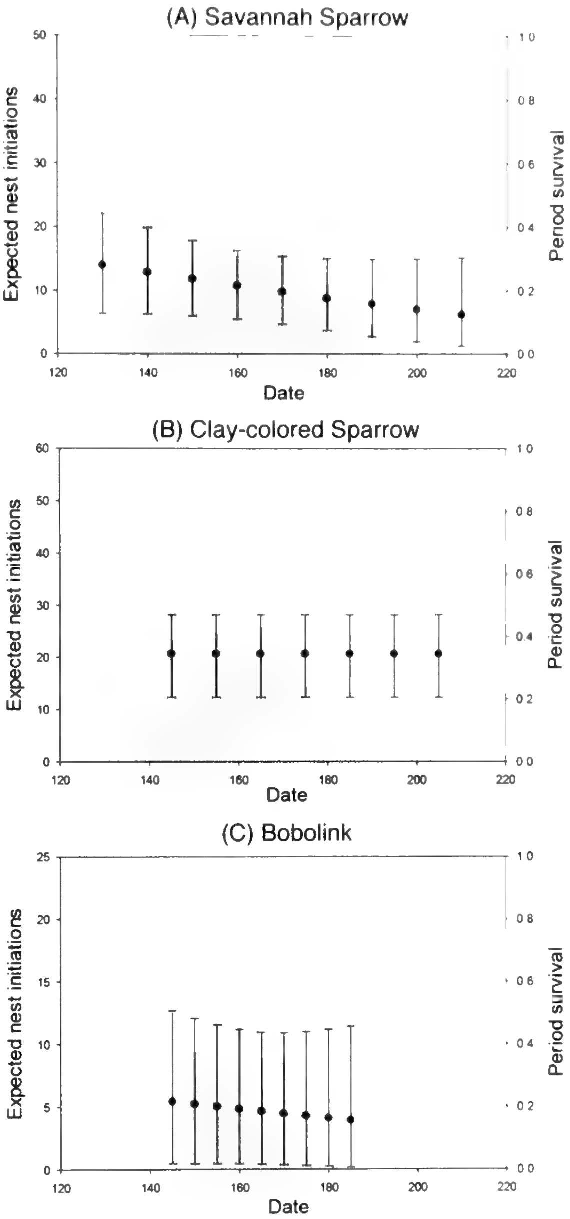

FIGURE 2. Estimated number of nest initiations and period nest survival rates for (A) Savannah Sparrow (*Passerculus sandwichensis*), (B) Clay-colored Sparrow (*Spizella pallida*), and (C) Bobolink (*Dolichonyx oryzivorus*) in relation to ordinal date in North Dakota. Solid circles (with 95% confidence intervals) denote estimated probability of a nest surviving from laying through fledging when initiated on specific dates that span the nesting period (mean 1998–2003). Shaded bars indicate the expected number of nests initiated on each date. Expected initiations account for nests that did not survive long enough to be discovered.

The timing of nest initiations for Clay-colored Sparrows, Savannah Sparrows, and Bobolinks generally corroborates findings from recent studies in the northern Great Plains (Davis 2003; Winter *et al.* 2004; Jones *et al.* 2010; B. C. Dale, Canadian Wildlife Service, unpublished data). The Savannah Sparrow is among the first passerine species to arrive on breeding sites and initiate nests in our area, followed about 7–10 days later by the Clay-colored Sparrow. Both species are persistent renesters after nest failure and can raise two clutches per season in the northern Great Plains (Wheelwright and Rising 2008; Grant and Knapton 2012). Despite the fact that individuals were not marked in our study, double-brooding can be inferred by a multimodal peak of nest initiations, clearly evident for the Savannah Sparrow. In contrast, Clay-colored Sparrows do not initiate second nests (after successfully fledging the first brood) every year; this practice depends on arrival dates or other site-specific factors not well understood (Grant and Knapton 2012). This may explain the lack of multimodal pattern of nest initiations across six years in our study. The Bobolink is among the last grassland songbird species to arrive in our area. Bobolinks initiate nests later and have a shorter breeding period (composed of a single concentrated peak of nesting) than either sparrow species. Although replacement clutches are common after nest failures, Bobolinks may be restricted to one brood per season in the northern portion of their range (Gavin 1984; Winter *et al.* 2004).

Nest survival

Survival can vary with age of the nest and nest initiation date in both grassland passerines and upland-nesting ducks, although time-specific patterns in survival rates are reportedly inconsistent among regions and species (Emery *et al.* 2005; Grant *et al.* 2005; Davis *et al.* 2006; Grant and Shaffer 2012). Survival was highest for nests initiated early in the breeding season for five of the seven species in our study. Nest survival has also been reported to be higher early in the season for ducks and passerines breeding elsewhere (Flint and Grand 1996; Winter *et al.* 2004; Emery *et al.* 2005; Thompson *et al.* 2012). Grant *et al.* (2005) observed a similar, but more compelling, pattern of survival relative to initiation date for Clay-colored Sparrow and Vesper Sparrow, as did R. K. Murphy (United States Fish and Wildlife Service, unpublished data) for Clay-colored Sparrow and Savannah Sparrow nesting in northwestern North Dakota. Early nesting may have conferred survival advantages for grassland species in our study (reviewed in Grant and Shaffer 2012). Fitness may increase for females or broods if higher-quality nests are initiated early in the season (Blums *et al.* 2005), when the density of nests or nest predators is lower (Nams 1997; Grant *et al.* 2006) or in cases where predators, such as small mammals, are associated with specific vegetation height and density parameters that change throughout the season (e.g., Dion *et al.* 2000). For the Clay-colored Sparrow and Savannah Sparrow, early successful nesting increases the probability of double-brooding within the same nesting season. Furthermore, early-hatched offspring may have survival advantages over later-hatched young during both the pre- and post-fledging periods (Rohwer 1992; Amundson and Arnold 2011).

Is timing of nesting adaptive?

An adaptive response (in terms of long-term fitness) could be inferred if patterns of nest initiation corresponded with patterns of nest survival. Grant *et al.* (2005) demonstrated that more nests were initiated early in the season when nest survival also was high (approximated by a linear decline in survival with date) for Clay-colored and Vesper Sparrows in North Dakota. In our study, Gadwalls and Clay-colored Sparrows initiated more nests early in the season, but evidence was at best equivocal regarding an adaptive response similar to that described by Grant *et al.* (2005). Alternatively, nest initiation patterns of the Savannah Sparrow, Mallard, Northern Shoveler, Blue-winged Teal, and Bobolink more closely approximated a normal distribution, with a greater proportion of nests initiated mid-season. Nesting chronology did not consistently match patterns of nest survival for any species we studied; survival tended to be greater early in the season or was not influenced by date.

We conducted a separate correlation analysis that allowed the relation between timing of nesting and nest survival to vary among years for each species. This analysis reduced potential masking of year-specific relations between survival and initiations that may be meaningful (i.e., when data were considered across all 6 years of study). We found marginal evidence that timing of nesting was positively associated with nest survival, at least during some years, for the Savannah Sparrow and Bobolink but not for other species. In theory, negative correlations between nest initiations and period survival that we observed for ducks may reflect years when nest survival is low and renesting effort is high. When considered across all species–year combinations, this analysis provided scant evidence to suggest that any species we considered initiated more nests during periods when survival was greater.

Although predation was the main cause of nest failure in our study (T. A. G., unpublished data), our results indicate that nest predation was not the primary influence on timing of nesting for the species we considered. The apparent mismatch between date-specific patterns of nest survival and number of nest initiations in our study underscores uncertainty about general processes of avian nest site selection (timing of nesting in our case) as random or non-random events driven by predation risk (e.g., Chalfoun and Schmidt 2012). Given our results, factors other than nest survival may better explain nesting chronology for the species we considered. Chief among these are food availability for females or offspring; predation risk for nesting females, duck broods, or post-fledged passerines; climate effects on brood survival (e.g., heat stress) — factors for which we lack data to address (e.g., Drever and Clark 2007; Dunn *et al.* 2011). Understanding these relations may be further complicated in highly modified landscapes, such as ours, where evolutionary mechanisms that shaped nest site selection may no longer apply.

Conservation Implications

Few studies have examined factors that affect duck and songbird nesting simultaneously in the same location. Survival decreased with nest initiation date for five of the seven species we studied, and this pattern is also reflected in recent studies across multiple species within the region (Winter *et al.* 2004; Grant *et al.* 2005; Thompson *et al.* 2012; R. K. Murphy United States Fish and Wildlife Service, unpublished data). Although early nesting conveyed survival advantages for several species in our study, patterns of nest initiation did not match patterns of survival in any predictable fashion.

Timing and number of nest initiations in ducks can be partly predictable, based on age of the hen, spring temperatures, precipitation, or wetland availability (Hammond and Johnson 1984; Greenwood *et al.* 1995; Krapu 2000). Similar data for passerines are not available in our region, providing an opportunity and a need for additional study. For some duck species we studied, onset of nesting was later than historic data show for the same location, warranting additional study into the scope and significance of this phenomenon. Ducks initiated nests 10–20 days earlier than passerines, suggesting the potential for spring management activities to affect each taxonomic group differentially.

Knowledge about timing of nesting may allow biologists to identify benefits and consequences of proposed actions. For example, spring grazing or burning can reduce height and density of vegetation used as nesting cover, thereby altering density of bird nests. Furthermore, the presence of cattle during nest initiation can reduce nest densities in some grassland species, suggesting that managers may be able to adjust timing of grazing to reduce avoidance of an area when livestock are present (Bowen and Kruse 1993; Kruse and Bowen 1996). In northwestern North Dakota, grazing during May and June reduced nest densities for late-arriving Blue-winged Teals and Gadwalls, but not for early breeding Mallards that initiated many nests before cattle were present (Kruse and Bowen 1996). Our data suggest that grazing could be delayed until after nesting is well underway in June, if bird nesting is the only consideration. Haying on National Wildlife Refuges in North Dakota is programmatically delayed until 1 August to protect nesting birds. Based on our data, all duck and Bobolink nests and > 98% of Clay-colored and Savannah Sparrow nests would have been completed by this date.

Population monitoring in general and nest searching activities in particular are expensive and time consuming. We concur with recommendations from Grant *et al.* (2005) to locate nests early in the egg-laying stage and throughout the breeding season to facilitate time-specific analyses of survival. However, if resources are limited and time-specific effects are not of primary interest, monitoring and research activities could target periods when many nests of multiple species are active.

Acknowledgements

Funding was provided by the United States Fish and Wildlife Service, Region 6 Divisions of Refuges and Wildlife and Migratory Bird Management and by the United States Geological Survey, Northern Prairie Wildlife Research Center. S. K. Davis shared his experience and methods for locating and monitoring nests of grassland passerines. S. L. Jones provided support throughout the project. E. M. Madden and G. B. Berkey were pivotal in completing the study. C. M. Aucoin, K. M. Baus-Christopherson, B. Bedard, K. J. Berg, B. Cofell, M. J. Friel, J. Gault, S. L. Finkbeiner Kempema, K. M. Hansen, S. Kuzyk, R. A. Laubhan, S. A. Marshall, R. T. McManus, M. P. Nenneman, and J. J. Thury assisted with data collection. Comments by F. E. Durbian, T. A. Arnold, and an anonymous reviewer improved the manuscript. The findings and conclusions in this article are those of the authors and the United States Geological Survey and do not necessarily represent the views of the United States Fish and Wildlife Service. The use of trade, product, or firm names in this article is for descriptive purposes only and does not imply endorsement by the United States government.

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Received 19 May 2014
Accepted 8 August 2015

Aspen Parkland Pasture Altered by Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) Activity: The Good, the Bad, and the Not So Ugly?

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Newediuk, Levi J., Isobel Waters, and James F. Hare. 2015. Aspen parkland pasture altered by Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) activity: the good, the bad, and the not so ugly? Canadian Field-Naturalist 129(4): 331–341.

Although Richardson's Ground Squirrels (*Urocitellus richardsonii*) are considered pests throughout their North American range, their impact on forage in Canadian aspen parkland has not been explored. We investigated the effect of Richardson's Ground Squirrel density on forage quality and plant community composition in an intensely grazed cattle pasture in the aspen parkland region of Manitoba, Canada. We detected no significant differences in forage protein content or legume, grass, and litter biomass among ground squirrel density levels. However, ground squirrel density did influence the abundance of invasive and forage plant species; greater squirrel density reduced the prevalence of Smooth Brome (*Bromus inermis* Leysser) and Red Clover (*Trifolium pratense* L.) and increased the abundance of Quackgrass (*Elymus repens* (L.) Gould) and Black Medick (*Medicago lupulina* L.). Plant community diversity also increased with ground squirrel density. There were no differences in soil bulk density or ammonia content among squirrel density levels; however, soil nitrate content was highest at low ground squirrel density. Changes in available soil nitrogen and relative abundances of forage species on this pasture may affect cattle diet by altering both the availability and quality of forage. Our findings highlight the need for further investigation of the role of Richardson's Ground Squirrel on rangeland in the aspen parkland region to ascertain the generality of the effects documented in our study. Until such effects and their implications for cattle production are understood, land managers should refrain from exterminating colonies of Richardson's Ground Squirrel.

Key Words: Richardson's Ground Squirrel; *Urocitellus richardsonii*; aspen parkland; intermediate disturbance; community structure; rangeland; cattle; grazing

Introduction

In North America, ground squirrels (tribe Marmotini [Sciuridae]) contribute significantly to forage crop and livestock losses. In Montana, alfalfa crop losses range from 24% to 31% in areas of high ground squirrel density, resulting in annual financial losses as high as $7 million state-wide (Johnson–Nistler *et al.* 2005). Similarly, in California, ground squirrels reduce alfalfa crop yield by 39–48%, imposing an annual cost of $233–335/ha (Whisson *et al.* 1999). In a United States-wide survey, rodents, including ground squirrels, accounted for over 15% of wildlife-caused losses reported by livestock producers (Wywialowski 1994), either via competition for forage (Howard *et al.* 1959) or perceived animal injury resulting from uneven ground caused by burrowing (Jameson 1973; Calder 2003). Given the economic importance of agricultural production, several studies have explored the feasibility of ground squirrel management methods, such as poisoning and shooting, in terms of cost effectiveness and effects on crop and animal yield (Whisson *et al.* 1999; Johnson-Nistler *et al.* 2005).

Despite evidence suggesting adverse effects of ground squirrels on agricultural land, the universal acceptance of Richardson's Ground Squirrels (*Urocitellus richardsonii*) as pests remains controversial. Although few scientific studies have been conducted that describe the effects of ground squirrels on pastureland, they have been regarded as major agricultural pests in the aspen parkland and mixed prairie regions of Canada since the late 19th century. Calder (2003) suggests that this perception stems from the traditional view that the production potential of agricultural land is compromised by its use by native wildlife. The foraging activities of prairie dogs (*Cynomys* spp.), which are of similar concern to agricultural producers but occur south of the aspen parkland, reportedly reduce forage biomass (Winter *et al.* 2002), increase the nitrogen content of forage through compensatory growth (Coppock *et al.* 1983), and promote the presence of short- to mid-height perennial grasses (Winter *et al.* 2002) and exotic species (Fahnestock and Detling 2002). The effect of ground-dwelling rodents on the distribution of plant species may be particularly important to livestock producers, where they influence the distribution of toxic and nutritionally important forage species. Despite the paucity of empirical evidence for either improvement or degradation of agricultural land quality by ground-dwelling rodents in Canadian agricultural areas, extermination of ground squirrels is both accepted and encouraged (Calder 2003).

An empirical understanding of ground squirrel impacts on pastureland is critical for the development of economical and environmentally sound pasture management practices on the Canadian prairies. The complete removal of ground squirrel colonies may have adverse effects on the pastureland community by limiting nitrogen input and disrupting predator–prey relationships. Elimination of ground squirrels from pastureland may also affect pasture quality by limiting soil aeration, which may reduce soil compaction caused by cattle trampling (Houlbrooke *et al.* 2009), or by reducing water infiltration to deeper layers of the soil profile where burrows were once present (Laundre 1993). Finally, reducing the density of ground squirrels on pastureland may compromise the persistence of such species as the endangered Burrowing Owl (*Athene cunicularia*), which relies on abandoned ground squirrel burrows for nesting habitat (Poulin *et al.* 2005).

Given the controversy surrounding Richardson's Ground Squirrels on pastureland, we conducted a preliminary study to assess changes in forage quality on a pasture in the aspen parkland region of Manitoba, Canada. We compared forage and soil characteristics across three ground squirrel foraging densities within a single pasture, so as to unambiguously ascribe any treatment effect to ground squirrel density and not confound that assessment with myriad biotic and abiotic factors that vary considerably among pastures. We hypothesized that soil nitrogen and crude protein content of forage would increase with ground squirrel foraging density and that available forage biomass, moisture, and bulk density would decrease with foraging density. We also hypothesized that plant species diversity would peak at intermediate density (as predicted by the intermediate disturbance hypothesis [Grime 1973]), and that plant species assemblages would differ across foraging densities.

Study Area

The study site was a cultivated 7.4-ha pasture located just east of Westbourne, Manitoba (50°10'4"N, 98°30'10"W). The pasture has been grazed intensively since 1970, with cattle stocking rate during our study at five head/ha. Because of that relatively high stocking rate, combined with the apparent homogeneity of the pasture, we were confident that all areas of the pasture had an equal probability of being grazed by cattle. Indeed, the topography of the site is generally flat, without temporary or permanent wetlands, and it lacks any large-scale changes in plant community structure or any obvious disparities in cattle-grazing activity. The soil type is clayey lacustrine (black chernozems), with consistent texture throughout the pasture. Forage grasses with the greatest percentage cover include introduced species, such as Smooth Brome (*Bromus inermis* Leysser), Quackgrass (*Elymus repens* (L.)), and native Kentucky Bluegrass (*Poa pratensis* L.). Black Medick (*Medicago lupulina* L.) and Red Clover (*Trifolium pratense* L.) are also common (Table 1). These and other legumes have been seeded in the region to enhance the feed value of pastures (McCartney 1993). All species identified pasture-wide are listed in Table 1 according to abundance.

TABLE 1. Pasture-wide forage species, in order of descending abundance in an aspen parkland pasture in Manitoba.

Rank	Species
1	Kentucky Bluegrass (*Poa pratensis* L.)
2	Red Clover (*Trifolium pratense* L.)
3	Quackgrass (*Elymus repens* (L.) Gould)
4	Smooth Brome (*Bromus inermis* Leysser)
5	Black Medick (*Medicago lupulina* L.)
6	Common Dandelion (*Taraxacum officinale* F. H. Wiggers)
7	Canada Thistle (*Cirsium arvense* (L.) Scopoli)
8	Garden Bird's-foot Trefoil (*Lotus corniculatus* L.)
9	Flodman's Thistle (*Cirsium flodmanii* (Rydberg) Arthur)
10	Common Plantain (*Plantago major* L.)
11	Common Timothy (*Phleum pratense* L.)
12	Unidentified forb
13	Common Silverweed (*Potentilla anserina* L.)
14	Unidentified forb
15	Unidentified forb
16	Unidentified forb
17	Northern Fairy-candelabra (*Androsace septentrionalis* L.)
18	Unidentified forb
19	Unidentified forb
20	Unidentified forb

Methods

Estimating Ground Squirrel Density

Three ground squirrel foraging densities were determined by subdividing the site based on observations of aboveground squirrel activity and burrow use. Burrows provide refuge for squirrels disturbed during foraging (Batzli and Sobaski 1980; Davis 1984) and are often surveyed to estimate local ground squirrel abundance (Proulx *et al.* 2012). Because Richardson's Ground Squirrels cluster in areas with dense concentrations of active burrows, we assumed that foraging was most intense where burrows were most frequently used. We made observations on three dates: 3, 9, and 12 June 2010, starting at least 2 weeks after juvenile emergence had ended so that males and females of all age classes were active above ground. Sampling was conducted over a 2-h period between 0900 and 1500 central daylight time, under conditions suitable for aboveground activity by ground squirrels, on days without precipitation or strong wind, and with temperatures between 10°C and 27°C. Three observers marked squirrel sightings at burrow entrances in an observation area of 1–2 ha each using scan sampling (Martin and Bateson 1986). Because we were concerned only with total foraging activity, rather than activity of individual squirrels, sightings were recorded regardless of whether the individual had already been sampled. Observers rotated through different areas of the pasture to avoid observer bias. We recorded locations of burrow entrances using a WAAS (wide area augmentation system)-corrected Garmin GPS 72 with accuracy of ± 5 m (Garmin Ltd., Olathe, Kansas, USA).

We used the locations of burrow entrances to create a density map of ground squirrel foraging intensity in Arc GIS using the animal movement extension (ESRI, Redlands, California, USA). We defined 5-m-radius buffers around each sighting location to account for squirrel foraging distance from the burrow entrance, given that core areas used by juvenile ground squirrels for burrowing and feeding are approximately 50 m^2 at 5–6 weeks of age and, typically, do not exceed approximately 250 m^2 within the first season preceding hibernation (Michener 1981). As buffers approximated foraging distances from the burrow entrance, foraging was considered to be most frequent where buffers overlapped. We designated areas in which at least two buffer layers overlapped as high-foraging-density areas and those with a single buffer layer as intermediate-density areas. We assumed that squirrels had been locally extirpated from areas with no sightings over the 3 sampling days, attributing the absence of squirrels in those areas to intensive, and yet patchily distributed removal by shooting, which the pasture's owners reported to have occurred in the summer of 2009. However, as it was impossible to conclude definitively that squirrels did not at least occasionally use those areas, we conservatively designated them as low-density areas (Figure 1).

Within each density level, we generated 20 random sample points, which we located on 22 June 2010, subject to the restriction that those points on site contained both vegetation and soil and were undisturbed except for grazing. If a generated sample point did not contain vegetation representative of the pasture in general (i.e., if it was located on a cow pat or mound, or contained a burrow entrance), a new random sample point was generated. To independently verify high-, intermediate-, and low-density areas, we counted the number of active and inactive nest and escape burrow entrances in non-overlapping 20 × 20 m quadrats surrounding the centre of each sample point on 29 June 2010. Within each quadrat, we recorded the number of active burrow entrances, which we identified to be those with visible recent excavation. We subcategorized active burrow entrances into escape entrances, which exceeded the girth of an adult ground squirrel, and nest entrances, which equaled the girth of an adult ground squirrel. Burrow entrances that were closed or overgrown with vegetation and had no evidence of recent excavation were considered to be inactive. Although each sample point was marked with a metal spike and flagging tape, several of them became impossible to locate over the course of the season despite attempts using GPS and an MD3005 metal detector (Famous Trails, Anaheim, California, USA). For this reason, sample size was reduced for a number of measurements.

Vegetation Sampling

From 22 to 24 June 2010, we clipped all aboveground portions of plants at ground level in two 25 cm × 25 cm quadrats per sample point and placed the harvested vegetation and litter in either paper bags for dry biomass determination (n = 20 per density level) or sealable plastic bags for crude protein determination (n = 10 per density level). To prevent overlap with vegetation surveys, we placed the quadrats northwest (biomass) and southeast (protein) of the sample point, with the corner of each quadrat touching the marker. We considered shoots to be in the quadrats if they were rooted on or within the edge of the quadrat. Before harvest, we estimated average vegetation height in each dry biomass quadrat using the drop disc method (Stewart *et al.* 2001). A 30 cm-diameter corrugated plastic disc weighing 54.29 g and with the centre cut out to fit over a metre stick was dropped from a height of 50 cm into the centre of the quadrat. When the disc came to rest, we recorded its height on the metre stick (to the nearest mm). The width of the plastic (4 mm) was subtracted from all height measurements.

The vegetation harvested for dry biomass determination was dried in a 65°C oven to a constant weight (40 h), and the average weight of a dried paper bag (obtained from a sample of 20 paper bags) was subtracted from this to obtain the total vegetation weight per quadrat. Following drying and weighing, we sorted vegetation into three categories: grasses, legumes, and non-leguminous forbs. We placed the sorted vegetation in new paper bags and dried it at 65°C to a constant weight (additional 5 h per bag), to control for moisture that may have been transferred to the vegetation from the air or hands during the sorting process. Sorted vegetation was weighed again to obtain the dry mass of grasses, legumes, and non-leguminous forbs.

Vegetation harvested for protein determination was transported to the laboratory on ice. To reduce variation in samples due to differences in species composition among quadrats, we used only tissue of two of the most common species, *Medicago lupulina* and *Poa pratensis*, for crude protein analysis. We weighed out 8 g of leaf tissue from each species for each harvested quadrat

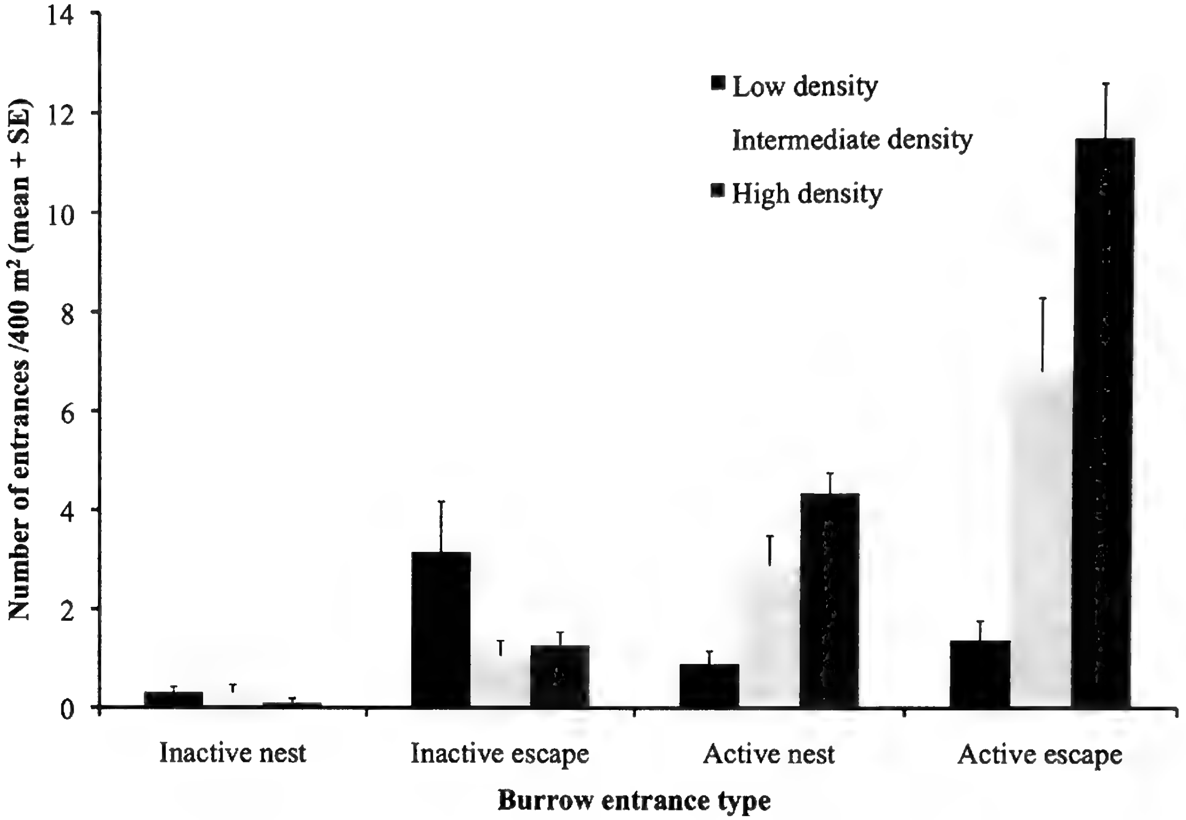

FIGURE 1. Number of burrow entrances in 400-m^2 plots in 19 low-, 20 intermediate-, and 18 high-density Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) areas in Manitoba. Nest burrow entrances equaled the girth of an adult ground squirrel. Escape burrows were defined as all of those that exceeded the girth of an adult ground squirrel. Active burrows had signs of recent excavation. Burrows with entrances closed or overgrown with vegetation and with no evidence of recent excavation were considered to be inactive.

and wrapped it in aluminium foil. We then flash froze the tissue by submerging the foil packets in liquid nitrogen for 20 s, and immediately placed them into a freezer at −80°C for subsequent protein analysis (see below). Because harvests were performed mid-season, forage nutrition content was likely at a moderate level (Wallace *et al.* 1972).

Crude Plant Protein Determination

We processed and prepared the flash-frozen leaf tissue of *Medicago lupulina* and *Poa pratensis* for protein determination by grinding tissue samples in liquid nitrogen. We extracted the protein using 25 mL of cold phosphate buffer (pH 7.0) following the methods of Jones *et al.* (1989). A solution of 1 mM EDTA, 1% polyvinylpyrrolidone, and 1 mM ascorbate was added to the buffer as a protein protectant (Zhao *et al.* 2008). We allowed extraction to proceed on ice for 20 minutes, then centrifuged the homogenate at 4°C for 20 minutes at 15 000 g. We measured protein content in 15 mL of the supernatant using the Bradford (1976) method. A bovine serum albumin standard was used to create a standard curve after each preparation of the phosphate buffer.

Vegetation Surveys

On 29 and 30 June 2010, we estimated plant species cover in 1 m × 1 m quadrats placed at the northeast corner of each sample point. At this point in the season, forbs and grasses should have amassed 30% and 50% of their maximum seasonal organic matter, respectively (Wallace *et al.* 1972). We estimated the percentage cover of each species to the nearest 1%, except when species were present in trace amounts. These species were given values of either 0.7% (one moderate-sized plant or two to three small plants) or 0.1% (one small plant). We considered individual plants to be in the quadrat if they were rooted on or inside the quadrat edge. The same two observers estimated percentage cover in all quadrats to avoid sampling bias and ensure consistency of estimates among quadrats; the two independent estimates of each species were averaged.

Soil Moisture

We measured soil moisture at each sample point on 29 June 2010 (48 h since rain) using a theta probe (Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA). Although moisture sampling on multiple dates would have given a more meaningful estimate of overall moisture, few days in the 2010 season would have provided accurate moisture estimates because of frequent rainfall, as soil in this region remains saturated for up to 5 days following rain. Measurements were taken 15 cm to the northwest, northeast, southwest, and southeast of each sample point for a total of four readings; these were averaged to obtain a single moisture value for each sample point.

Soil Bulk Density

We obtained soil for bulk density determination by cutting out soil cores 5 cm in diameter to a depth of 10 cm about 30 cm northeast of the sample points and filling the holes with a known volume of sand measured in a 100-mL graduated cylinder to determine volume. In the laboratory, we dried the cores at 105°C for 24 h. We calculated bulk density by determining weight/volume for each soil core.

Inorganic Nitrogen Analysis

On 29 and 30 July 2010, we used a 20-cm auger to obtain a single soil core about 30 cm southwest of each of the 44 sample points (14 high density, 15 low density, and 15 intermediate density). We air dried and ground the cores until the soil passed through a 2-mm sieve. We then weighed out 100 g of soil for nitrate analysis. Each 5.0 g of air-dried soil was extracted with 25 mL of 2 M KCl solution and shaken on a reciprocating shaker for 30 minutes at 150 excursions per minute. The resulting extract was then centrifuged for 90 minutes at 3100 rpm. Nitrate/nitrite and ammonia concentrations in the resulting supernatant were determined using the cadmium reduction method (Clesceri *et al.* 1998).

Data Analysis

Although our study was conducted in a single pasture and, thus, represents a single replicate within the aspen parkland region as a whole, each sample point was treated as a separate sample for analysis of the effects of ground squirrel density on the pasture. Differences in burrow entrance density (n = 16) and vegetation and soil characteristics — including plant height (n = 18), dry biomass (n = 18), average percentage cover per species (n = 18), and crude protein (n = 8), as well as soil nitrate/nitrite (n = 14), ammonia (n = 14), bulk density (n = 14), and moisture (n = 18) — among the three squirrel density levels (high, intermediate, and low) were analyzed using one-way analysis of variance in Data Desk (Data Description, Inc., Ithaca, New York, USA). Soil nitrate data were log transformed before analysis. All results were considered significant where $P \leq 0.05$ because effect sizes could not be estimated before performing the analyses (Mudge *et al.* 2012).

We analyzed plant community data using multiple discriminant analysis (MDA) in Syn-Tax 5.1 (Exeter Software, Setauket, New York, USA) to evaluate differences in species composition among high, intermediate, and low ground squirrel density areas. MDA is a multivariate technique for significance testing among individuals that have been defined as belonging to *a priori* groups (Brook and Kenkel 2002). This makes it an ideal method for exploring differences in the plant community in areas with different ground squirrel densities. The analysis compared species composition for each individual (quadrat) by maximizing within-group variation in species composition along p axes corresponding to the number of principal components analysis (PCA) axes used as input in the MDA eigenanalysis. PCA axes were used as input to reduce the number of variables in the MDA analysis. We evaluated the significance of the MDA axes using Wilke's lambda, which was considered significant where $P \leq 0.05$.

We also compared diversity among ground squirrel density levels using Simpson's index:

$$[1] \quad D = \frac{\sum n(n-1)}{N(N-1)}$$

where n is the abundance of a species, and N is the total abundance of all species. We selected this index because Simpson's index weights rare species less heavily than common species (Simpson 1949). Our study was concerned with major shifts in the plant community caused by ground squirrel activity and, therefore, rare species (those accounting for < 1% cover) were not considered significant to the questions at hand. Evenness among density levels was calculated using Kvålseth's (1991) equation:

$$[2] \quad E_\alpha = {}^{N_\alpha}/_{N_{\alpha-1}}$$

where $N_\alpha = (\sum p_i{}^{\alpha})^{1/(1-\alpha)} - 1 = s_\alpha - 1$

is the number of defined species, and α is a parameter with a real number value. Whittaker plots comparing log percentage cover of species in order of decreasing abundance were used to compare evenness and diversity among squirrel density levels (Whittaker 1972).

Results

Ground Squirrel Density

Although the number of inactive burrow entrances did not differ significantly among Richardson's Ground Squirrel density levels, the number of active escape and nest burrow entrances increased significantly from low- to high-density areas (Figure 1; $F_{2,52} = 26.18$, $P < 0.0001$). Variation in the number of active nest burrow entrances within each quadrat (0–8 entrances) was not as broad, however, as that for active escape burrows (0–21 entrances).

Plant Community

MDA revealed a transition in common grass and legume species from high to low ground squirrel foraging density. Separation of the three ground squirrel density groups was maximum along the first MDA axis ($\Lambda = 0.59$, $P < 0.001$). In other words, the *a priori* groups (foraging densities) of sample points were distinct from one another along the first axis in terms of plant species composition. PCA biplot scores of plant species superimposed on the MDA ordination revealed that percentage cover of *Elymus repens* and *Medicago lupulina* increased with increasing ground squirrel density. In contrast, *Bromus inermis* and *Trifolium pratense* percentage covers were greatest at lower squirrel densities (Figure 2). *Medicago lupulina* and *Elymus repens* differed most in magnitude among ground squirrel density levels ($F_{2,54}$ = 4.75, $P < 0.05$; $F_{2,54}$ = 6.20, $P < 0.01$), while *Bromus inermis* and *Trifolium pratense* differed less among density levels, but the difference was still significant ($F_{2,54}$ = 3.73, $P < 0.05$; $F_{2,54}$ = 4.85, $P < 0.05$; Table 2). Percentage cover of all legumes in low-density quadrats tended to be higher than in either high- or intermediate-density quadrats, although this difference was not statistically significant ($F_{2,54}$ = 1.62, $P > 0.20$; Table 2).

Plant species diversity, as measured by Simpson's index (*D*) (with Kvålseth's evenness (*E*)), was higher in plots with high ground squirrel density (*D* = 0.73, E_{21} = 0.09) than in plots where ground squirrel density was low or intermediate (*D* = 0.69, E_{21} = 0.13; *D* = 0.68, E_{21} = 0.11 respectively). In Whittaker plots of log percentage cover of species versus rank abundance (ordi-

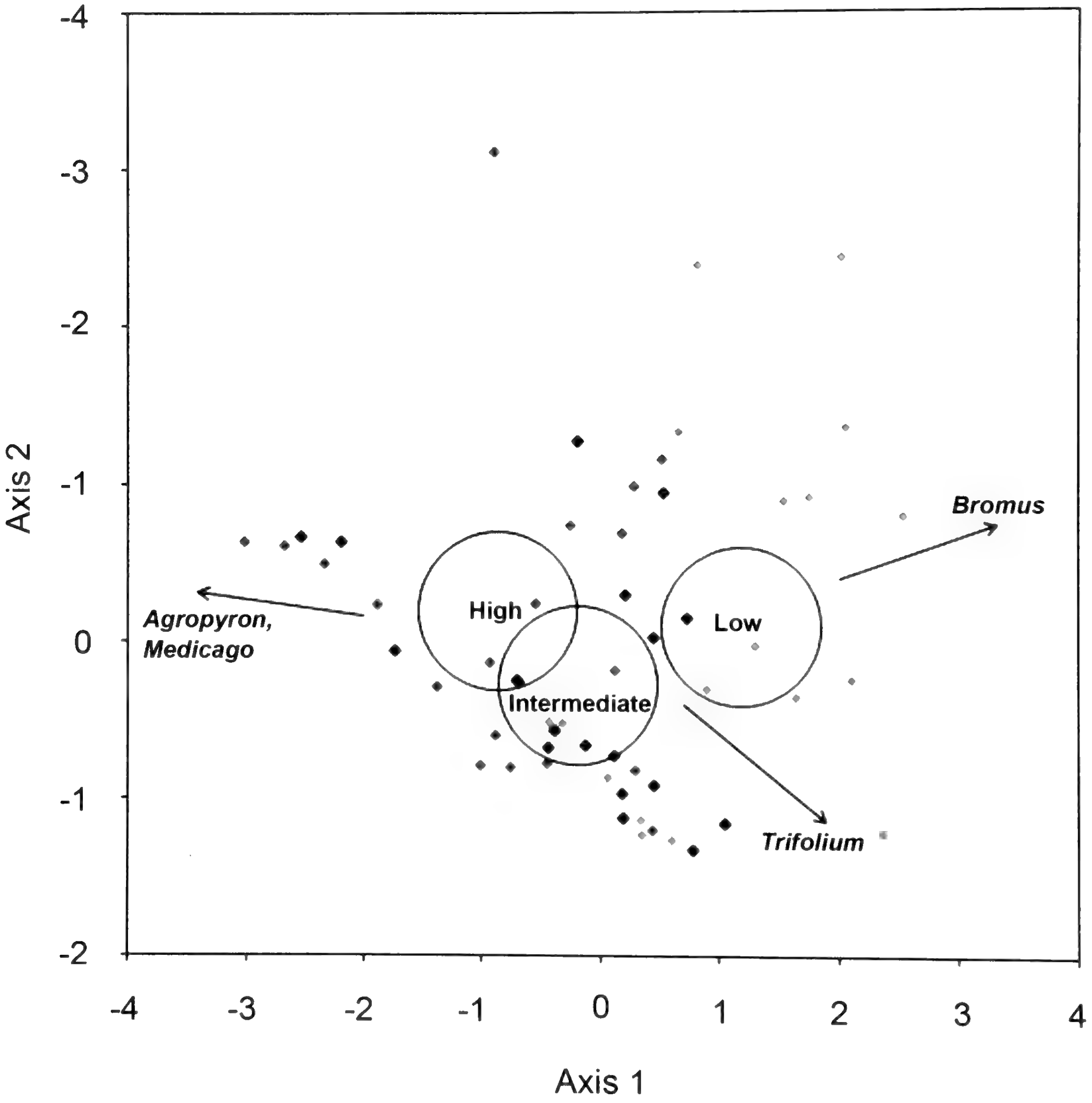

FIGURE 2. Multiple discriminant analysis ordination of principal components analysis (PCA) axes comparing plant species composition in quadrats (individuals) in 38 low-density, 38 intermediate-density, and 38 high-density Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) areas in Manitoba. Circles represent 95% confidence ellipses for groups. Arrows represent biplot scores of species on PCA axes for *Bromus inermis*, *Elymus repens*, *Medicago lupulina*, and *Trifolium pratense*. Axis 1 is statistically significant (Λ = 0.59, $P < 0.001$).

TABLE 2. Forb, legume, and grass cover (mean ± standard deviation) in areas of high, intermediate, and low density of Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) and pasture-wide in an aspen parkland pasture in Manitoba.

	Squirrel density areas			
	Low (n = 19)	Intermediate (n = 20)	High (n = 18)	Pasture-wide
Forbs				
*Medicago lupulina**	3.8 ± 0.7 a	8.4 ± 2.3 ab	11.3 ± 1.8 b	7.8 ± 1.1
*Trifolium pratense**	31.2 ± 5.3 a	18.2 ± 3.5 b	14.3 ± 2.8 b	21.2 ± 2.5
Cirsium arvense	0.5 ± 0.4	2.5 ± 1.8	1.1 ± 0.6	1.1 ± 0.6
Lotus corniculatus	0.9 ± 0.5	2.0 ± 1.0	0.0	1.0 ± 0.4
Taraxacum officinale	2.3 ± 0.7	1.8 ± 0.6	0.1 ± 0.1	1.4 ± 0.3
Other forbs†	0.1 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
Total forbs	2.5 ± 0.6	2.2 ± 0.4	1.8 ± 0.3	2.1 ± 0.3
Total legumes‡	35.9 ± 5.4	28.7 ± 3.5	25.6 ± 3.1	10.0 ± 1.1
Grasses				
*Bromus inermis**	16.2 ± 5.4 a	3.3 ± 1.6 b	6.7 ± 3.2 a	8.8 ± 2.3
*Elymus repens**	7.3 ± 1.9 a	16.6 ± 3.4 b	26.4 ± 5.4 b	16.8 ± 2.4
Poa pratensis	65.7 ± 4.0	70.4 ± 3.9	55.8 ± 6.8	64.2 ± 3.0
Phleum pratense	0.1 ± 0.1	0.7 ± 0.5	0.6 ± 0.4	0.5 ± 0.2
Total grasses§	89.3 ± 7.2	93.1 ± 4.7	87.8 ± 4.5	22.6 ± 2.0

*Different letters indicate significant differences among density levels ($P < 0.05$).
†Includes species with average percentage cover below 0.5%: *Cirsium floodmanii*, *Plantago major*, *Phleum pratense*, *Potentilla anserina*, *Androsace septentrionales*, and seven unidentified species.
‡Includes *Medicago lupulina*, *Lotus corniculatus*, and *Trifolium pratense*.
§Includes the four species listed in the table.

nal list of species from most to least abundant), low-density areas tended to have fewer species, with a few contributing greatly to plant abundance and others contributing very little (Figure 3). Low squirrel density areas had the fewest number of species and the most variation in abundance among those species (Figure 3), appearing as a geometric series (Whitaker 1972). The high and intermediate squirrel density areas were typified by lognormal distributions, a greater number of species overall, and more even distribution of each of those species throughout the area (Figure 3).

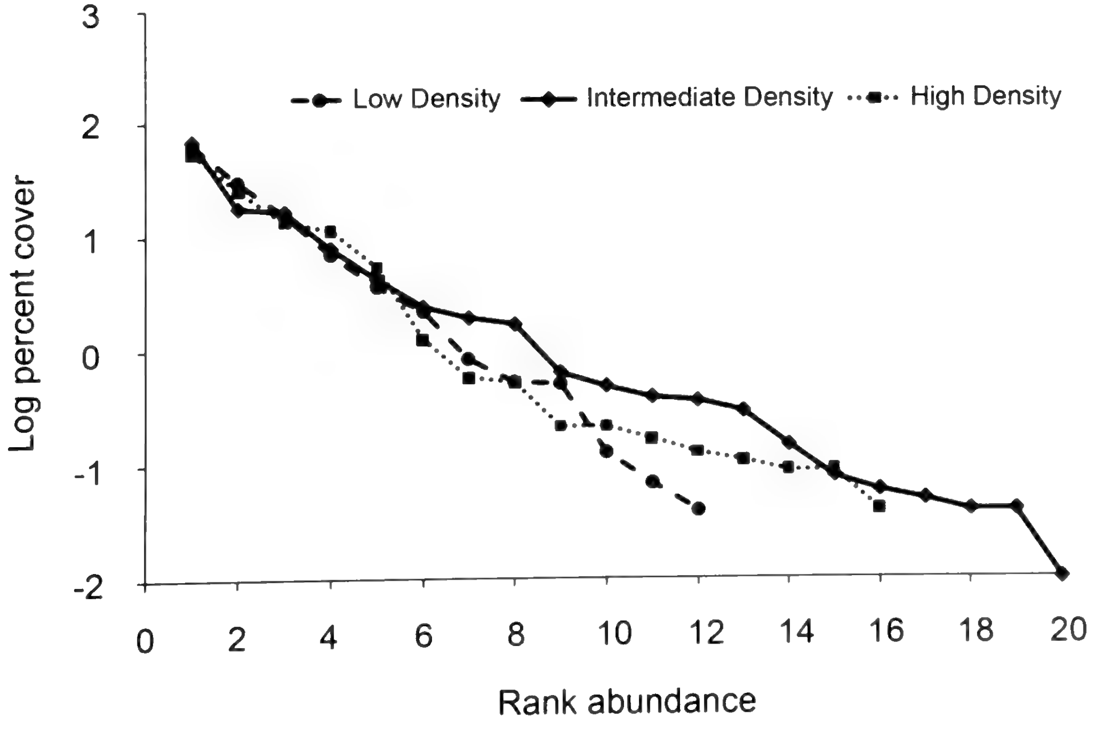

FIGURE 3. Whittaker plot showing differences in log percentage cover of plant species in decreasing order of abundance for 12 low-density, 16 intermediate-density, and 20 high-density Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) areas in Manitoba.

Vegetation Characteristics

There were no significant differences in protein content of either *Medicago lupulina* ($F_{2,28} = 0.74$, $P = 0.50$) or *Poa pratensis* ($F_{2,29} = 1.57$, $P > 0.20$), vegetation height ($F_{2,51} = 1.67$, $P > 0.20$), or forage biomass ($F_{2,51} = 0.16$, $P > 0.80$) among the three squirrel density levels (Table 3). However, there was a slight decreasing trend in biomass of legumes, grasses, and total forage from low to high ground squirrel density. This trend likely reflects a decrease in available forage from low to high density. The high legume biomass in low-density areas relative to intermediate- and high-density areas was striking, although it still fell short of statistical significance ($F_{2,49} = 2.09$, $P > 0.10$).

Soil Characteristics

Soil nitrate/nitrite content was significantly higher in low ground squirrel density areas than either intermediate- or high-density areas ($F_{2,40} = 332.37$, $P < 0.01$; Table 4). Soil moisture was also significantly higher in low-density than high-density areas ($F_{2,52} = 3.82$, $P < 0.05$; Table 4). However, this result must be interpreted cautiously, given that moisture samples were taken on only one day in a summer season with atypically high precipitation (Environment Canada reports 481.4 mm of rain for 2010 in this region, with 37.1% of that accumulating between June and July, whereas mean annual precipitation is 514.5 mm with 75.6% of that falling as snow between October and April). There were no significant differences in soil ammonia or bulk density among density levels (Table 4).

TABLE 3. Mean dry biomass per quadrat (± standard deviation) for legumes, grasses, forage, and litter, plant biomass density, plant height, and crude protein content for *Medicago lupulina* and *Poa pratensis* at three Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) density levels in an aspen parkland pasture in Manitoba.

	Squirrel density			
	Low	Intermediate	High	*n*
Legumes				
Total biomass, g/m*	15.0 ± 3.6	15.8 ± 2.4	6.8 ± 2.1	18
Proportion	0.2 ± 0.1	0.2 ± 0.0	0.1 ± 0.0	18
Grasses				
Total biomass, g/m†	53.7 ± 5.0	50.0 ± 4.5	47.8 ± 5.1	18
Proportion	0.8 ± 0.1	0.8 ± 0.0	0.9 ± 0.0	18
Total forage biomass, g/m‡	68.8 ± 4.2	65.8 ± 5.0	54.7 ± 4.7	18
Litter, g/m	37.5 ± 4.1	32.8 ± 4.2	35.4 ± 3.8	18
Plant biomass density, g/m^3	392.3 ± 50.6	459.1 ± 100.0	292.8 ± 45.0	18
Plant height, cm	5.4 ± 0.4	6.7 ± 1.0	5.0 ± 0.3	18
Crude protein				
Medicago lupulina, µg/g	30.6 ± 10.3	25.8 ± 4.4	42.4 ± 11.1	8
Poa pratensis, µg/g	19.6 ± 1.3	22.9 ± 1.4	19.4 ± 1.7	8

*Includes *Medicago lupulina*, *Trifolium pratense*, and *Lotus corniculatus*.
†Includes *Phleum pratense*, *Elymus repens*, *Poa pratensis*, and *Bromus inermis*.
‡Includes all grass and legume species in addition to trace amounts of forb species not reported individually.

TABLE 4. Soil characteristics (mean ± standard deviation) in plots with low, intermediate, and high densities of Richardson's Ground Squirrel (*Urocitellus richardsonii* Sabine) in an aspen parkland pasture in Manitoba.

	Squirrel density		
Soil characteristic	Low	Intermediate	High
Moisture, mV*	714.28 ± 18.58 a	678.83 ± 22.41 ab	634.18 ± 19.69 b
Bulk density, g/cm^3	0.97 ± 0.04	0.92 ± 0.04	0.94 ± 0.03
Nitrate/nitrite content mg/kg*	14.57 ± 4.58 a	5.83 ± 0.78 b	5.96 ± 1.23 b
Ammonia content, mg/kg	4.74 ± 0.24	5.62 ± 0.87	4.14 ± 0.21

*Different letters indicate significant differences between density levels ($P < 0.05$).

Discussion

Our study set out to assess changes in forage quality caused by Richardson's Ground Squirrel foraging activities on a pasture in Manitoba's aspen parkland region. The positive correlation between active burrow counts and number of above ground individuals in high-, intermediate-, and low-density areas suggests that the contrast among those areas in terms of squirrel foraging activity is robust. It is unlikely that differences among density levels were the result of underlying spatial heterogeneity in microhabitat, given the absence of any obvious environmental gradients delineating those areas or any difference in topography or soil type, density, moisture, or ammonia levels among them. In fact, although the abundance of inactive burrows in the low-density areas implies that lagging effects of high-intensity ground squirrel foraging before local extirpation may be at work, it also indicates that these low-density areas were suitable for occupancy by ground squirrels and, thus, were qualitatively equivalent to the current high-density areas before squirrels were removed in 2009.

Forage Quality Changes and Implications for Cattle

In our study, Richardson's Ground Squirrels did not have a significant impact on crude protein content or available forage (in terms of biomass and height), which is inconsistent with our hypotheses. However, increased ground squirrel density was associated with significant reductions in soil nitrate content and plant community composition, which shifted away from *Bromus inermis* and *Trifolium pratense* with concomitant increases in *Elymus repens* and *Medicago lupulina* cover. Crude protein content of legume hays containing *T. pratense* has been shown to exceed that of *M. lupulina* hays (Kiraz 2011). The increase in *M. lupulina* cover relative to *T. pratense* in our pasture may affect forage nutritional quality, although our study detected no differences in protein content among ground squirrel density levels on a per-species basis. For example, an increase in *T. pratense* over *M. lupulina* in high-density ground squirrel areas may increase pasture-wide crude protein available to cattle. Alternatively, the increase in the ratio of *Elymus repens* to *Bromus inermis* associated with increasing squirrel density may decrease protein availability for cattle, as fresh *B. inermis* forage exceeds *E. repens* in crude protein content in all but spring pasture (McCartney 1993; National Research Council 1996a). Energy acquired from feed cannot be used by beef cattle for growth and maintenance of tissues if it is not balanced with respect to amino acid supply (Kerley 2012). Therefore, the promotion of the availability of high-protein forages by Richardson's Ground Squirrels may contribute to improved cattle weight gain in the region, as long as forage biomass is not also significantly reduced.

Our results conflict with the drastic changes in forage quality often attributed to ground-dwelling rodents. For example, in a study of effects of the Black-tailed Prairie Dog (*Cynomys ludovicianus*) on a plant community in Texas, standing crop off-colony was more than three times that on-colony (Weltzin *et al.* 1997). Howard *et al.* (1959) reported that removal of California Ground Squirrels (*Otospermophilus beecheyi*) from California pasture for 2 years significantly increased available plant biomass. However, studies documenting these dramatic effects were performed between the mixed-grass prairie of the central Great Plains region (Coppock *et al.* 1983) and northern California (Howard *et al.* 1959). Both biotic and abiotic conditions change with altitude and region, and this may account for the discrepancy between results obtained in the current and previous studies.

Further, because our study focused on the effects of Richardson's Ground Squirrels on a cattle-grazed pasture, we did not include any off-colony plots, which may prove integral to the detection of significant impacts of ground-dwelling rodents on pastureland vegetation, as areas without grazing by squirrels would preclude any influence of past foraging effects. For example, Fahnestock and Detling (2002) detected no difference in the number of forb species among prairie dog exclosed and non-exclosed plots on colonies, but did note a significant difference in the number of forb species among on-colony and off-colony plots.

Alternatively, our failure to detect a significant difference in forage protein content and available biomass could result from our relatively small sample size and the extensive variability among samples. Future studies require more intensive sampling and adequate replication to fully assess the influence of ground squirrel density on the availability and protein content of forage.

Ground Squirrel Foraging and Species Diversity

Grime (1973) suggested that in disturbed environments, diversity is greatest at an intermediate and optimal disturbance level where plants adopting stress-tolerator and competitor strategies are equally able to cope. Intermediate levels of foraging pressure have also been suggested to optimize plant productivity in terms of both growth and nutrient content (McNaughton 1979). In our study, the highest diversity (species richness and evenness) was observed at intermediate squirrel density, consistent with the intermediate disturbance hypothesis and confirming our hypothesis that moderate foraging activity by Richardson's Ground Squirrels at our site may enhance plant species diversity. It remains unclear, however, whether the highest measured diversity in our study represents the maximum species diversity (in terms of richness and evenness) for this pasture, or indeed for other pastures in the region. Future studies should replicate measurements across both time and space to capture a larger range of ground squirrel densities.

Changes in forage quality associated with the reduction of *Bromus inermis* and *Trifolium pratense* in high-density areas may be offset by increases in pasture diversity. As noted above, plant species diversity was highest where squirrel density was intermediate. This trend, at least in part, is attributable to the reduction in *B. inermis* with increasing squirrel density. Despite its original use as a rangeland forage species (McCartney 1993), *B. inermis* is an invasive grass in southwestern Manitoba and has been shown to decrease plant diversity and the abundance of native species in mixed-grass and fescue prairies by up to 70% (Otfinowski *et al.* 2007). The processes by which Richardson's Ground Squirrels control this species are unclear, but could include selective removal of plant tissue through herbivory or clipping, facilitation of competitors, such as *Elymus repens*, or by damage to tissues through soil disturbance.

Changes in Legume Abundance and Implications for Cattle

In addition to altering species composition, ground squirrel density appears to affect relative grass–legume abundance, contributing to spatial heterogeneity in soil inorganic nitrogen concentrations. Grasses and legumes are expected to coexist at equilibrium at various abundances depending on soil nitrate. When soil nitrate is low, nitrogen fixers (legumes) have an advantage and, therefore, should have a higher equilibrium abundance; when soil nitrate is high, uptake by non-fixers (grasses) should be more efficient and their equilibrium abundance should be greater (Thornley *et al.* 1995). Consequently, soil nitrate would be expected to be highest where the density of animals and, thus, the intensity of urination (nitrogen input) is highest; by the same logic, these areas should also contain the lowest abundance of nitrogen-fixers.

In the current study, the highest soil nitrate levels were detected in low ground squirrel density areas, which is inconsistent with our hypothesis. Those low-density areas also had the highest legume abundance, which, on the surface, appears paradoxical. Entz *et al.* (2001) report, however, that soil nitrate values greater than 8 mg/kg in the southern Manitoba region are high. Thus, the average nitrate values between 5.83 and 14.57 mg/kg observed on our pasture are relatively high for the region, and it is unclear whether the difference between high- and low-density areas (although significant) captures enough variation in nitrate content to influence the competitive interaction between legumes and grasses.

Lower soil nitrogen in high-density areas may be caused by reduced input of organic matter into soil surrounding the intensely grazed plants. Derner *et al.* (1997) found that although total nitrogen is generally higher in the vicinity of caespitose grasses in mid- and tall-grass prairie, the trend is reversed on intensely grazed sites because grazing-adapted grasses produce less biomass and, thus, do not contribute as much organic matter to the surrounding soil. Finally, it is unclear whether the decrease in legume abundance in high ground squirrel density areas equates with a reduction in the number of individual plants, the size of plants, or the proportion of resources allocated to shoot-versus-root growth, all of which would produce measurable decreases in legume shoot biomass and cover.

Cattle may benefit directly from the reduction in the ratio of legumes to grasses available in ground squirrel rich areas. Although legumes are important constituents of cattle forage owing to their high crude protein, pectin, and mineral content relative to grasses, the over-consumption of legumes by cattle results in nitrogen wastage by denitrification in legume-dominated pastures (Laidlaw and Teuber 2001). This may further reduce nitrate availability and compound shifts in relative grass–legume abundance. Moreover, cattle are prone to bloat when grazing intensively on legumes, including *Trifolium pratense* and *Lotus corniculatus*. Maintenance of a grass–legume sward reduces the incidence of bloat (Laidlaw and Teuber 2001) and has been emphasized repeatedly in the literature as a means of producing optimal grazing conditions for cattle (e.g., National Research Council 1996b; Harris *et al.* 1998).

Although Richardson's Ground Squirrels modified plant species composition and nutrient cycling on the pasture in our study, their effects on forage availability and nutrient content are not as clear. Where other research has explored the effects of ground-dwelling squirrels on rangeland forage (in South Dakota, Wyoming, California), the ability to detect dramatic changes in forage quality may be explained by larger sample sizes and replication across space and time, as well as the inclusion of off-colony sample plots. That caveat aside, within the limits of the present study, ground squirrel density increased species diversity and appears to have altered forage quality for the grazing cattle. Although the fact that we sampled plots of differing ground squirrel densities within a single pasture precludes generalizing our findings to other pastures in the aspen parkland region, our findings clearly suggest the need for an expanded research agenda, wherein the conditions under which ground squirrels alter the quality of pastureland are identified and the mechanisms underlying both the negative and positive effects of ground squirrel–cattle co-foraging are further elucidated.

Acknowledgements

We thank the Johnston family of Westbourne, Manitoba, for the use of their pasture and Dr. John Markham and Dr. Sylvie Renault for consultation and use of laboratory space, equipment, and chemicals throughout the study. Rob Ellis performed the soil nitrate analysis. Dr. Norm Kenkel performed the multivariate statistical analyses and aided in interpretation of results. Peter Tarleton assisted with collection of field data. We thank two anonymous referees and *Canadian Field-Naturalist* editors for their valuable comments, which improved the quality of our manuscript.

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Received 4 September 2013
Accepted 2 November 2015

Distribution of the Exotic Pond Slider (*Trachemys scripta)* in Ontario

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Seburn, David C. 2015. Distribution of the exotic Pond Slider (*Trachemys scripta)* in Ontario. Canadian Field-Naturalist 129(4): 342–348.

The Pond Slider (*Trachemys scripta*) is a turtle native to the eastern United States, but, because of its popularity in the pet trade, it now occurs in many countries around the world as a result of escapes and the release of unwanted pets. The distribution of the Pond Slider in Ontario is reviewed based on 393 records obtained from various sources. Sliders have been reported from 130 spatially distinct sites in 35 districts. The Toronto area accounts for 67% of records, and more than 80% of reports are from urban areas. Pond Slider reports date back to the 1950s, but 63% of records are from 2010 or later. Sliders have been observed in Ontario during all months of the year except December. Sliders have bred in Ontario, but the spatial extent of successful reproduction remains unknown.

Key Words: Pond Slider; *Trachemys scripta*; invasive species; turtle; citizen science; pet trade

Introduction

The Pond Slider (*Trachemys scripta*) is a turtle native to eastern and central United States (Ernst and Lovich 2009). It has long been popular in the pet trade, with over 50 million exported from the United States from 1989 to 1997 (Global Invasive Species Database 2010). Most individuals in the pet trade belong to one subspecies, the Red-eared Slider (*T. s. elegans*). Although hatchlings are only 3 cm long (carapace length), adults can reach 30 cm (Ernst and Lovich 2009). The size of adults makes keeping them in captivity difficult because of the large aquaria required.

The large size and potential longevity of the species has resulted in the release or escape of many pet turtles. For example, 44% of households that previously owned a Red-eared Slider in Singapore had released the turtle (Ng 2009). The global pet trade has resulted in individuals being released beyond their natural range within the United States, including Hawaii (Ernst and Lovich 2009) as well as countries in Europe (e.g., Cadi and Joly 2003; Perez-Santigosa *et al.* 2008), Africa (Baard and de Villiers 2000), Asia (Haramura *et al.* 2008; Xu *et al.* 2012), Oceania (Burgin 2006; Feldman 2007), and South America (Iriarte *et al.* 2005; Alcalde *et al.* 2012). The Pond Slider is now the world's most widespread freshwater turtle (Ernst and Lovich 2009) and is considered one of the 100 most invasive species in the world (Lowe *et al.* 2000). Recognizing the threat of this invasive species, the European Union banned the import of Red-eared Sliders (but not other subspecies) in 1997 (Global Invasive Species Database 2010).

The effect of Pond Sliders on native turtle species is not well known. Sliders have been observed to compete for basking locations with native turtle species (Cadi and Joly 2003, 2004; Spinks *et al.* 2003). Native European Pond Turtles (*Emys orbicularis*) experienced both weight loss and high mortality in areas where Pond Sliders also occurred (Cadi and Joly 2004). Sliders may also be more efficient predators than some other turtle species (Nishizawa *et al.* 2014), and the presence of juvenile Pond Sliders can reduce the growth rate of other juvenile turtles when food resources are limited (Pearson *et al.* 2015). The ongoing release of exotic Pond Sliders into natural ecosystems also increases the risk of introducing non-native parasites (Oi *et al.* 2012) or spreading serious diseases, such as ranaviruses, to native turtles and other species (Johnson *et al.* 2007; Brenes *et al.* 2014).

Sliders have been confirmed to breed successfully in some introduced areas, including Spain (Perez-Santigosa *et al.* 2008), France (Cadi *et al.* 2004), Italy (Ficetola *et al.* 2009), Australia (O'Keefe 2009), Taiwan (Chen 2006), California (Spinks *et al.* 2003), and southwestern Ontario (Gillingwater 2013). Up to 98 nests a year have been reported from one site in Italy (Crescente *et al.* 2014). The potential reproductive output of Pond Sliders is considerable, as females nest as early as age 5 years and can lay multiple clutches a year (Perez-Santigosa *et al.* 2008).

Sliders have been reported from Ontario since the early 1950s (Lamond 1994), but their status and distribution has not been examined in detail. Currently seven of Ontario's eight native freshwater turtles are considered species at risk (Ministry of Natural Resources and Forestry 2015). The widespread presence of an exotic turtle species could have negative effects on native turtles. This paper summarizes what is known about the distribution of Pond Sliders in Ontario based on observations submitted to various citizen science monitoring programs and other sources.

Methods

Records were obtained from the Turtle Tally program of the Toronto Zoo, the Ontario Herpetofaunal Summary, the Ontario Reptile and Amphibian Atlas, published scientific literature, communications with biologists, and my own observations. The records from monitoring programs include observations until the end

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A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalist's Club.

of 2013; observations from biologists extend to 2015. Twelve records had to be excluded because the reported latitude and longitude were within the Great Lakes or outside Canada. The major divisions of Ontario are referred to as districts in this paper, which include counties and regional municipalities. The number of discrete sites with Pond Sliders was determined by buffering all points using a 1.0-km radius using QGIS 2.0 Dufour (QGIS 2015). Buffered points that overlapped were considered to be part of the same site. A smaller radius would likely have produced more distinct sites, but would have separated some sites along rivers that are likely not isolated.

Results

A total of 393 records of Pond Sliders from across southern Ontario were obtained (Figure 1) representing 130 spatially distinct sites. The most northerly report of a Pond Slider was from just north of Kearney (45.5838°N). Sliders were reported from 35 districts. The city of Toronto accounted for 45% of all records and six Toronto area districts (Durham, Halton, Hamilton, Peel, Toronto, and York) made up 67% of the records. Urban areas accounted for more than 80% of all records. Most records were presumed to be Red-eared Sliders, as the red head stripes are the easiest diagnostic feature. Only one record specifically mentioned a Pond Slider without red head stripes (19 May 2003, from Cedar Creek Conservation Area in Essex county), but this does not confirm another subspecies as the head stripes can fade with age (Gillingwater and MacKenzie 2015).

The earliest known record from Ontario is a Pond Slider "at the mouth of Chedoke creek on the south shore of Cootes Paradise in the early 1950s" observed by G. A. Meyers (Lamond 1994). Most records (63%) are from 2010 or later (Figure 2). Sliders have been reported from Ontario in all months of the year except December (Figure 3). The earliest observation date was 12 January (2013) of a basking turtle in Toronto. The temperature that day reached 14.8°C at Pearson International Airport (Environment Canada 2015). The latest sighting date was 8 November (2009) with observations from three sites in Hamilton. The number of observations per month from April to August differed significantly with more observations in May than any other month ($\chi^2 = 12.006$, $P < 0.05$).

Most sites with observations of Pond Sliders have only one or a few observations of single turtles. The site with the greatest number of reported Pond Sliders is Grenadier Pond in High Park in Toronto. Sliders were first reported there on 20 September 1988, and up to 30 individuals have been observed at once (26 September 1993). Other sites with reports of at least five Pond Sliders include: Cootes Paradise in Hamilton (five observed on 30 June 2013), the Credit River in Mississauga (five observed on 8 August, 2013), Shoemaker Pond in Kitchener (six reported on 19 April 1996), Milliken Park in Toronto (seven observed on 18 August 2013), the Thames River in London (11 reported on 29 August 2013), and Ojibway Park in Windsor (at least 20 in 2012; Tom Preney, Ojibway Nature Centre, personal communication).

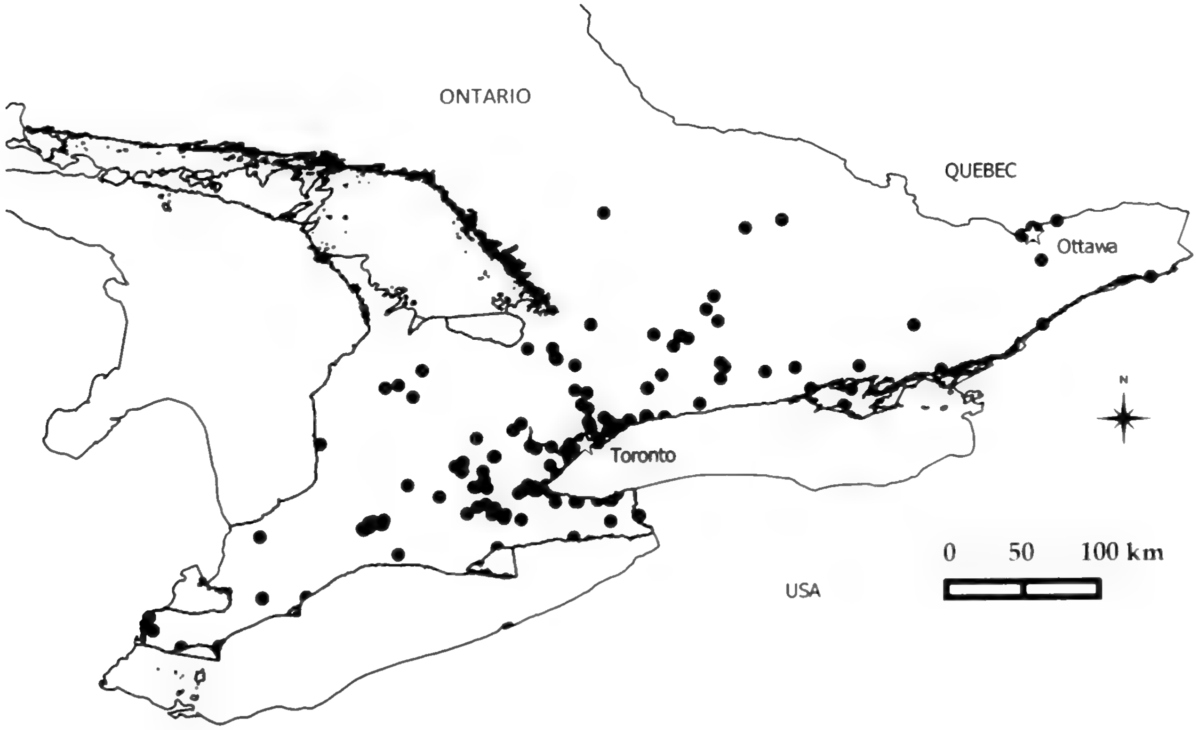

FIGURE 1. Location of 393 observations of the exotic Pond Slider (*Trachemys scripta*) in Ontario.

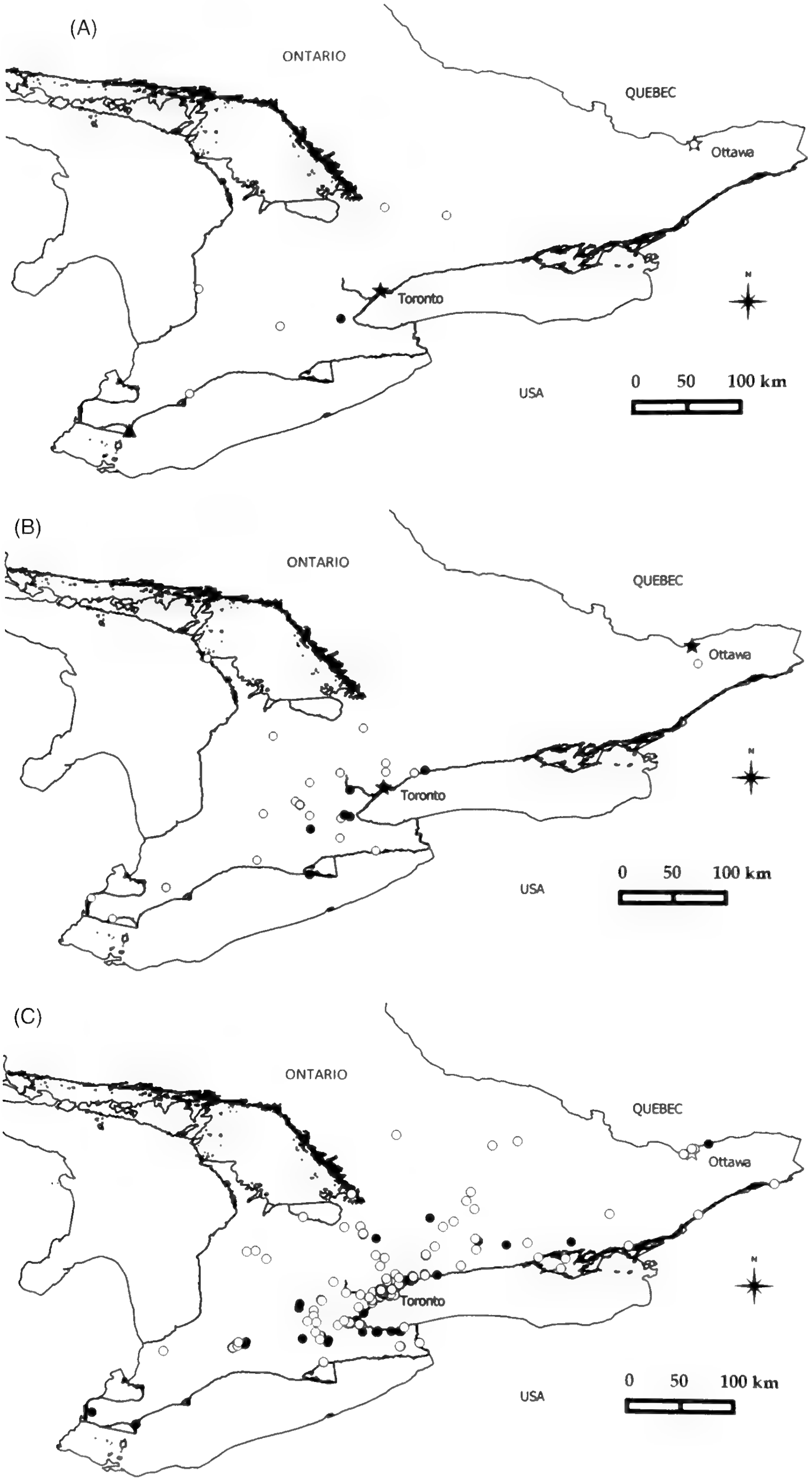

FIGURE 2. Location of observations of the exotic Pond Slider (*Trachemys scripta*) in Ontario by decade. (A) Observations from the 1950s (solid circles), 1960s (open circles), and 1970s (solid triangles). (B) Observations from the 1980s (solid circles) and 1990s (open circles). (C) Observations from the 2000s (solid circles) and 2010s (open circles).

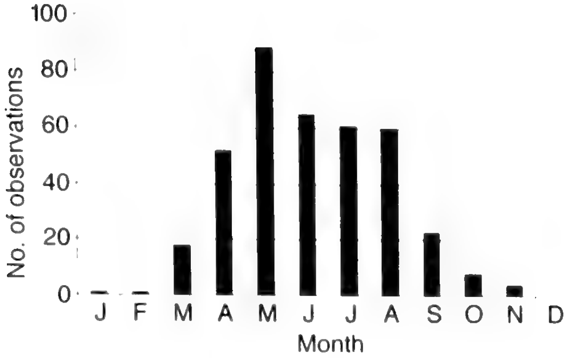

FIGURE 3. Frequency distribution of observations of the exotic Pond Slider (*Trachemys scripta*) in Ontario by month.

Twenty-one Pond Sliders, including four dead, were found on roads from 28 April to 17 October, with more such incidents reported in June than any other month. All but two observations (4 August 1990 in Bruce County and 3 July 1996 in rural Ottawa) were from 2009 or later. In addition to the four Pond Sliders found dead on roads, 12 dead Pond Sliders were found between 21 February and 29 May, possibly as a result of winter kill. Most reports were of individual dead turtles, but there were two observations of four dead Pond Sliders. The reports of multiple dead Pond Sliders were from Ojibway Park in Windsor (19 April 1994) and Lakeside Park in Kitchener (13 April 1997). Six of the 12 reports of dead Pond Sliders were from Lakeside Park in Kitchener, from 1994, 1996, and 1997.

The observation of Pond Sliders at the same site in multiple years suggests successful overwintering, although it is possible that new turtles were released each year. A Pond Slider in a former gravel pit near Orillia appears to have survived three winters (Jeff Hathaway, Scales Nature Park, personal communication). The most northerly location where Pond Sliders have been observed in multiple years is Britannia Conservation Area in Ottawa.

Observations of Pond Sliders in early spring are also suggestive of successful overwintering, as it seems unlikely that pet Pond Sliders would be released during cold weather. The report of a basking Pond Slider on 28 March in Toronto suggests that Pond Sliders can overwinter in southern Ontario. None of the 20 observations of Pond Sliders before the end of March are from locations north of the Toronto area. Only one of the 52 records from April is from north of Toronto: a Pond Slider found in Ottawa on 24 April 1962.

There were eight reports of Pond Sliders nesting in Ontario. As none of the observations provides any additional details, it is unclear whether the turtles were laying eggs. All of these observations were made between 14 May and 5 July, which corresponds to the typical turtle nesting period in Ontario. Although most of the observations are from the Toronto area, one report is from Peterborough and one from just south of Algonquin Provincial Park. Although not a nesting observation, I found an adult female Pond Slider wandering on land during the day, possible pre-nesting behaviour, at the Britannia Conservation Area in Ottawa on 18 June 2013. Three hatchling-sized Pond Sliders were found dead on roads in Windsor on three dates: 22 May 2013, 11 June 2013, and 27 May 2015 (Jonathan Choquette, SCC Ecological, personal communication). It is possible these turtles hatched in the wild, as adult Pond Sliders are known from the nearby Ojibway Park, but it is also possible that young Pond Sliders had been released in this area.

Discussion

There are many limitations to the data presented here. Twelve records had to be excluded because the data points were either from the middle of the Great Lakes or from the United States. It is unknown whether other locality information is incorrect, but still map within Ontario, as not all records include text descriptions of the locations. Despite some geographic uncertainty associated with the data, it is clear that Pond Sliders are widespread in southern Ontario. The distribution of Pond Sliders in Ontario is almost certainly underestimated, because many people assume that small basking turtles are Painted Turtles (*Chrysemys picta*). Also, one or two Pond Sliders among many Painted Turtles would be difficult to detect. In one case, an observation of two "Painted Turtles" submitted to the Toronto Zoo's Turtle Tally was accompanied by a photograph that revealed that one of the turtles was a Red-eared Slider. Without the photograph, the Pond Slider would have gone undocumented. There is also evidence that exotic species occurring at low densities will be overlooked by volunteer surveyors (Fitzpatrick *et al.* 2009). Nonetheless, citizen science programs are valuable in detecting exotic species across a broad geographic area (e.g., Delaney *et al.* 2008; Azzurro *et al.* 2013).

Significant increases in reports of Pond Sliders over the years may be because of an increase in released turtles, the growing popularity of monitoring programs, the proliferation of digital cameras making identification of turtles easier, or a combination of factors. For example, the increase in observations after the 1970s corresponds with the start of the Ontario Herpetofaunal Summary. The largest peak in data, in the 2010s, is a result of the Turtle Tally program of the Toronto Zoo, which was launched in 2003 but became very popular a few years later.

Sliders were available for sale in Toronto at least as early as 1945 (Francis Cook, Canadian Museum of Nature, personal communication). By 1960 over 150 turtle farms had been established in the southern United States to supply the demand in the pet trade (Ernst and Lovich 2009). This timeline suggests that Pond Sliders appeared in Ontario and were released into the wild soon after they entered the pet trade, as the first record from the province is from the 1950s in Hamilton.

By the end of the 1970s, Pond Sliders had been reported from only a few locations, and most of these were rural areas, including Rondeau Provincial Park and Point Pelee National Park. The only urban sites with reported Pond Sliders were in Hamilton and Ottawa. Either people were generally not releasing Pond Sliders in urban areas or observers were not reporting these releases. Sliders were not reported from High Park in Toronto until 1988, well after the Ontario Herpetofaunal Summary began in the early 1980s.

The observation of the largest number of Pond Sliders was 30 individuals in Grenadier Pond in High Park, Toronto, although it is uncertain how many Pond Sliders occur at this site. Exotic populations of Pond Sliders can reach large numbers: at least 125 were removed from a waterway in California (Spinks *et al.* 2003) and 662 were caught at four sites in Singapore (Ng 2009).

Winter mortality has been observed in Ontario, but it is unclear whether the small number of winter-killed Pond Sliders is because of successful overwintering or a lack of observations. Six of the 12 records of possibly winter-killed Pond Sliders were reported by one observer from one site in Kitchener, indicating that one dedicated observer can significantly influence results.

Over 80% of the reports of Pond Sliders were from urban areas. This is similar to results from California where most introduced Pond Sliders were found near urban areas (Thomson *et al.* 2010). If Pond Sliders are mainly limited to urban or suburban wetlands, then they may have less negative effect on native turtles. For example, at Point Pelee National Park, intensive survey work resulted in the capture of over 1500 turtles during 2001 and 2002, yet only three Pond Sliders were observed (Browne and Hecnar 2007). Similarly, turtle surveys at four natural sites along the north shore of Lake Erie from 1996 to 2015 resulted in the capture of over 2500 turtles, with only a single Red-eared Slider observed (Scott Gillingwater, Upper Thames River Conservation Authority, personal communication).

Although Pond Sliders can survive in many areas of the world, successful breeding is limited to a subset of these locations (Ficetola *et al.* 2009), mainly in areas with a climate similar to or warmer than the native range of the Pond Slider in southeastern United States (e.g., Kikillus *et al.* 2010). Sites with known breeding populations of Pond Sliders in Italy had warmer summer and winter temperatures than sites where breeding was not occurring (Ficetola *et al.* 2009). Climate change models suggest that Pond Sliders will be able to expand their breeding range greatly in Italy (Ficetola *et al.* 2009), and this will also likely be the case in Ontario, with feral Pond Sliders able to breed successfully beyond southwestern Ontario.

Hatchling Red-eared Sliders are currently for sale in many stores across Ontario (personal observation). Those that survive have a high probability of being released in the future when they become larger. One way to limit the release of Pond Sliders would be to ban their sale in Ontario, or at least ban the sale of turtles under a certain size. If the sale of hatchlings is stopped, then the market for Pond Sliders would likely be drastically reduced. There is precedent for this, as the United States banned the sale of domestic turtles less than 10 cm in length in 1975 because of the risk of salmonella (Ernst and Lovich 2009).

Although there is some evidence that exotic Pond Sliders can negatively affect native turtles (e.g., Cadi and Joly 2003, 2004; Spinks *et al.* 2003), there is limited information on their effects on turtles of eastern North America. For example, basking competition may not be a major issue in Ontario, as, within the native range of the Pond Slider, competition for basking sites is typically won by the largest individual turtle, regardless of the species (Lindeman 1999). Although Pond Sliders have been released across much of southern Ontario, it appears that most have been released in the Toronto area and other urban areas where the risk to native turtle populations is relatively low. The risk to other species groups may be greater. For example, Pond Sliders are confirmed transmitters of ranavirus to amphibians, while they are apparently unaffected by the disease themselves (Brenes *et al.* 2014). Without some control on the sale of Pond Sliders the number of individuals released into Ontario can only be expected to increase over time along with the risk of spreading disease.

Acknowledgements

I am grateful to all the dedicated volunteers who collected the Pond Slider observations and the various organizations that provided monitoring data for this review. Thanks to Jonathan Choquette, Francis Cook, Jeff Hathaway, Tom Preney, and Scott Gillingwater for their Pond Slider observations and to Rob Willson for GIS advice. This paper benefitted from review comments from Carolyn Seburn and two anonymous reviewers.

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Received 25 May 2015
Accepted 26 October 2015

Additions to the Boreal Flora of the Northwest Territories with a Preliminary Vascular Flora of Scotty Creek

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Garon-Labrecque, Marie-Ève, Étienne Léveillé-Bourret, Kellina Higgins, and Oliver Sonnentag. 2015. Additions to the boreal flora of the Northwest Territories with a preliminary vascular flora of Scotty Creek. Canadian Field-Naturalist 129(4): 349–367.

We present the first survey of the vascular flora of Scotty Creek, a peatland-dominated watershed with discontinuous permafrost about 60 km south of Fort Simpson, Northwest Territories (NWT). Of the 140 vascular plant taxa found at Scotty Creek, two are additions to the boreal flora of NWT: *Arethusa bulbosa* (Dragon's-mouth, Orchidaceae) and *Carex pauciflora* (Few-flowered Sedge, Cyperaceae). The occurrence of *Arethusa bulbosa* extends the known range of this species 724 km to the northwest, making this purportedly eastern American plant almost pan-Canadian. Two other major range extensions (> 200 km) are reported for *Carex brunnescens* subsp. *sphaerostachya* (Round-spike Brownish Sedge) and *Platanthera dilatata* var. *dilatata* (Tall White Bog Orchid). Furthermore, 15 other rare NWT species are reported, including three species known from a single other locality in the NWT. The flora of Scotty Creek is dominated by circumpolar (55%) and widespread North American (34%) elements. Despite the absence of exposed alkaline rocks and the dominance of deep organic soil almost throughout Scotty Creek, a number of lime-indicator plants were found in lakes and minerotrophic wetlands.

Key Words: *Arethusa bulbosa*; Dragon's-mouth; *Carex pauciflora*; Few-flowered Sedge; *Carex brunnescens* subsp. *sphaerostachya*; Round-spike Brownish Sedge; *Platanthera dilatata* var. *dilatata*; Tall White Bog Orchid; Fort Simpson; floristics; range extension; rare plants; Scotty Creek; Northwest Territories

Nous présentons la première étude floristique de Scotty Creek, un bassin versant dominé par un paysage de tourbières et caractérisé par un pergélisol discontinu localisé à environ 60 km au sud de Fort Simpson, dans les Territoires du Nord-Ouest (TNO). Un total de 140 taxons de plantes vasculaires ont été trouvés, dont deux sont nouveaux pour la flore boréale des TNO : *Arethusa bulbosa* (aréthuse bulbeuse, Orchidaceae) et *Carex pauciflora* (carex pauciflore, Cyperaceae). La nouvelle occurrence pour *Arethusa bulbosa* est distante de 724 km au nord-ouest de la plus proche mention connue. Cette espèce, qui était autrefois considérée comme limitée à l'est de l'Amérique du Nord, se retrouve maintenant avec une distribution presque pan-canadienne. Deux autres extensions d'aire de plus de 200 km ont été établies pour *Carex brunnescens* subsp. *sphaerostachya* (carex à épis globulaires) et *Platanthera dilatata* var. *dilatata* (platanthère dilatée). De plus, quinze espèces rares sont mentionnées, dont trois ne sont connues que d'une autre localité dans les TNO. La flore de Scotty Creek est dominée par des espèces circumpolaires (55%) et nord-américaines (34%). Malgré l'absence de roches alcalines et la dominance d'un sol organique profond presque partout sur le territoire, plusieurs plantes indicatrices de conditions calcaires ont été trouvées, notamment dans les lacs et dans les tourbières minérotrophes.

Mots clés: *Arethusa bulbosa*; aréthuse bulbeuse; *Carex pauciflora*; carex pauciflore; *Carex brunnescens* subsp. *sphaerostachya*; carex à épis globulaires; *Platanthera dilatata* var. *dilatata*; platanthère dilatée; Fort Simpson, floristique, Territoires du Nord-Ouest, extension d'aire, plantes rares, Scotty Creek

Introduction

As more attention is being paid to the impacts of economic development and climate change on the Canadian north, initiatives such as the Northwest Territories Biodiversity Action Plan (NWT Biodiversity Team 2005) are being undertaken to promote the protection of northern biodiversity and ecosystems. However, conservation of biological diversity depends on recognition of that diversity, which relies on primary taxonomic, floristic, and faunistic research (Expert Panel on Biodiversity Science 2010). Unfortunately, basic knowledge of the taxonomy and distribution of the flora and fauna of the Canadian north remains incomplete, even for relatively well-known taxa, such as vascular plants. For example, in the 28 years following the publication of Porsild and Cody's (1980) vascular plant flora of continental Nunavut and Northwest Territories (NWT), at least 151 plant species, or an average of 5.4 species per year, have been reported as new to one or both of these territories (Catling *et al.* 2005, 2008). This highlights the continued importance of exploration and floristic and taxonomic research for biological conservation, especially in the most remote areas of the Canadian north not accessible by car or boat.

This study documents the vascular flora of a remote area for which no exhaustive floristic survey has yet been published. Our botanical contribution aims to support ongoing environmental research at Scotty Creek by providing a list of vascular plants known to occur at, or in the larger vicinity of, the research camp. Furthermore, our survey provides some additions and new records to the boreal flora of the NWT, which may prove to be critical in the determination of conservation priorities and statuses.

Study Area

Scotty Creek (61.3°N, 121.3°W) is a hydrologically well-characterized 152-km^2 watershed with discontinuous permafrost about 60 km south of Fort Simpson, NWT, in the Mackenzie Plain subregion of the Taiga Plains ecoregion (NWT Protected Areas Strategy 2013). The area has a dry continental climate with long cold winters and short summers. The annual average temperature recorded between 1981 and 2010 at the Fort Simpson meteorological station is −4.8°C, while the average annual precipitation is 387.6 mm, with 48% from snowfall (Environment Canada 2014). The growing season, i.e., months during which average minimum daily temperature is above 0°C, lasts from May to September (Environment Canada 2014) and is characterized by up to 19.5 h of daylight (Kitto 1930).

For the past 15 years, research at Scotty Creek has focused primarily in the vicinity of a remote research camp (Quinton *et al.* 2009). The area surrounding the camp is generally flat and of low altitude (about 280 m above sea level). It was completely covered by the Laurentian ice sheet during the Last Glacial Maximum and up to 10 500–11 000 years ago (Duk-Rodkin and Lemmen 2000). Proglacial lakes have left compact clay deposits throughout most of the area (Hayashi *et al.* 2004), often covered by a thin silt–sand layer of presumed glaciofluvial origin (Duk-Rodkin 2011). These mineral deposits are now overlain by a peatland complex comprising mostly dry forested peat plateaus with permafrost (Figure 1), but also permafrost-free bogs, fens, and lakes, each with specific hydrological properties supporting different plant communities (Quinton *et al.* 2003). Peat thickness in the upper portion of Scotty Creek is up to 8 m (Hayashi *et al.* 2004). Two small lakes, First Lake and Goose Lake, are located close to the research camp. West of Goose Lake lies a small well-drained area covered by glacial and fluvioglacial deposits such as eskers, kame plains, and thin tills (Duk-Rodkin 2011).

FIGURE 1. Undergrowth on a typical semi-open peat plateau at Scotty Creek, Northwest Territories, summer 2013. Photo: Marie-Ève Garon-Labrecque.

Methods

Our floristic survey covered a 1.42 km^2 area of land and water, including a small lake (500 m × 500 m) known as First Lake and the southwestern section of a larger lake, Goose Lake, i.e., from approximately 61.292°N to 61.306°N, and 121.289°W to 121.310°W.

Specimens were collected in and around 102 quadrats placed randomly across the landscape and in various locations between the quadrats and the research camp. In addition, other sites were visited to cover species and habitats not found around and between the predetermined locations. At each site, sampling was conducted by meandering following apparent floristic and habitat variation until no new species or microhabitats were encountered, according to the recommendations of Goff *et al.* (1982) for efficient floristic surveys. The survey was conducted between 1 July 2013 and 11 August 2013, covering the greater part of the growing season. At least one voucher specimen of every species was deposited at the Marie-Victorin Herbarium, Université de Montréal (MT).

Identification keys used include Porsild and Cody (1980), the Flora of North America North of Mexico (Flora of North America Editorial Committee, eds. 1993+), Michigan Flora (Voss and Reznicek 2012), Faubert (2000), and Cayouette (2004). Herbarium specimens at the Marie-Victorin Herbarium (MT), Agriculture and Agri-Food Canada Collection of Vascular Plants (DAO), and the National Herbarium of Canada (CAN) were used to confirm some identifications. Taxonomy follows VASCAN, the Database of Vascular Plants of Canada (Brouillet *et al.* 2010+) except for the genus *Eriophorum* (Cyperaceae), for which names were taken from Cayouette (2004) with updated nomenclature from Väre (2007). Author abbreviations in taxonomic names follows the International Plant Names Index (2012). Herbarium abbreviations follow Index Herbariorum (Thiers 2014+). In the text, herbarium specimens that were examined are marked with an exclamation mark (!) after the herbarium acronym. Phytogeographic affinities of plant taxa were determined using distributional data in Porsild and Cody (1980), the Flora of North America North of Mexico (Flora of North America Editorial Committee 1993+), and Hultén's Circumpolar Plants (Hultén 1962, 1971).

We recognize the following floristic elements within the vascular flora of Scotty Creek: (1) circumpolar species with a distribution in Europe, Asia, North America, and sometimes also Greenland; (2) amphi-Beringian species with a distribution in eastern Asia and western North America; (3) East Asian–North American species with a distribution in eastern Asia and in western and/or eastern North America; (4) amphi-Atlantic species with a distribution in eastern North America and Europe; (5) widespread North American species with a distribution in both western and eastern North America; (6) western North American species with a distribution only in western North America; (7) eastern North American species with a distribution only in eastern North America.

Results and Discussion

Through this survey, 140 vascular plant species were identified in our study area, with two species and one subspecies new for the NWT. Nine territorially "sensitive" species and three species that "may be at risk" according to the Working Group on General Status of NWT Species (2011) are reported, but none has a conservation status at the national or global level (Government of Canada 2013; IUCN 2013; Natureserve 2015). This high proportion of territorially rare species might reflect the fact that Scotty Creek is relatively close to the provincial borders with British Columbia and Alberta, where species near the northern edge of their range are expected to be more common.

Phytogeographically, Scotty Creek is dominated by circumpolar vascular plants species (55%), with a significant proportion of widespread North American taxa (34%) and a few American–East Asian taxa (5%). Two taxa, *Arethusa bulbosa* L. and *Carex brunnescens* subsp. *sphaerostachya* (Tuck.) Kalela, have predominantly eastern American distributions (Toivonen 2002; Sheviak and Catling 2003). It is interesting that no species of fern was found, and there were only three grass (Poaceae) and two Asteraceae species.

The study area is dominated by semi-shaded peat plateaus (40%), partly treed channel fens and swamps (25%), collapse bogs (25%), and lakes (10%) (Chasmer *et al.* 2014). Swamps and marshes are mostly limited to the immediate surroundings of First Lake and Goose Lake. Peat plateaus are dominated by semi-shaded to open *Picea mariana* (Mill.) Britton, Sterns & Poggenb. (Black Spruce) forest growing on dry peat underlain by permafrost (Figure 1). Trees are stunted to a height of about 5 m, and their dead lower branches are covered with epiphytic lichens (e.g., *Usnea* spp., *Bryoria* spp.). *Rhododendron groenlandicum* (Oeder) Kron & Judd (Common Labrador Tea) and other ericaceous shrubs are common in the understory. The ground is entirely covered by lichens and bryophytes, such as *Cladonia stygia* (Fr.) Ruoss, *Cladonia mitis* Sandst., *Sphagnum fuscum* (Schimp.) H. Klinggr., *Sphagnum capillifolium* (Ehrh.) Hedw., *Stereocaulon* spp., and *Icmadophila ericetorum* (L.) Zahlbr. Sandy hills are less common in the area. They are characterized by dense, tall (up to about 10–15 m) *Pinus banksiana* Lamb. (Jack Pine) and *Picea mariana* growing on a sandy substrate covered by lichens. Fens are dominated by herbaceous species with scattered *Larix laricina* (Du Roi) K. Koch (Tamarack) and *Betula glandulosa* Michx. (Glandular Birch) on wet peat. They are generally open with an abundance of *Triglochin maritima* L. (Seaside Arrowgrass) and *Menyanthes trifoliata* L. (Bog Buckbean), or sometimes densely covered by Cyperaceae species (*Trichophorum alpinum* (L.) Pers., *Eriophorum* spp., and *Carex* spp.). The ground cover is dominated by

Tomenthypnum nitens (Hedw.) Loeske, *Aulacomnium palustre* (Hedw.) Shwägr., and various pleurocarp mosses. Bogs are species poor, with a dominance of ericaceous shrubs such as *Chamaedaphne calyculata* (L.) Moench (Leatherleaf), *Andromeda polifolia* L. (Bog Rosemary), and *Vaccinium oxycoccos* L. (Small Cranberry). *Scheuchzeria palustris* L. (Marsh Scheuchzeria), *Vaccinium oxycoccos*, and *Maianthemum trifolium* (L.) Sloboda (Three-leaved False Solomon's Seal) are also common, with a dominance of *Sphagnum balticum* (Russow) C.E.O. Jensen and *S. magellanicum* Brid. Bog ponds are infrequent, but wet depressions are often encountered where setting foot causes water resurgence from the peat and where *Scheuchzeria palustris* and *Maianthemum trifolium* are often abundant. Swamps near the edge of standing water are dominated by *Myrica gale* L. (Sweet Gale) or *Betula glandulosa*, with *Menyanthes trifoliata* and *Typha latifolia* L. (Broad-leaved Cattail) as common associates. Marshes are dominated by *Typha latifolia* and *Menyanthes trifoliata*, with a high abundance of *Comarum palustre* L. (Marsh Cinquefoil), *Calla palustris* L. (Wild Calla), and *Utricularia intermedia* Hayne (Flat-leaved Bladderwort). The two major lakes are covered with *Nuphar variegata* Engelmann ex Durand (Variegated Pond-lily) associated with many *Potamogeton* species (pondweeds).

Arethusa bulbosa, new to and widely disjunct in the NWT

Arethusa bulbosa (Dragon's-mouth, Orchidaceae) is reported as new to the NWT. The combination of a single, bright pink resupinate flower with the two lateral petals forming a hood over the white/yellow-mottled labellum (Figure 2), the absence of leaves during flowering, and its boggy habitat make this species unlikely to be confused with other native NWT orchids. At Scotty Creek, it was collected in full bloom in early July in a rich wet fen (see the annotated species list for more details). The main part of its range, where it is considered more common, is in northeastern North America, from Manitoba to Newfoundland, and down to northern West Virginia, with a disjunction in South Carolina in the United States (Sheviak and Catling 2003). The closest confirmed population of *A. bulbosa* occurs as a disjunction from the main range, in northwestern Saskatchewan (*Harms 23985*, SASK!; Argus 1962). The Scotty Creek population thus extends the known range of the species 724 km to the northeast. This new locality also makes the distribution of *A. bulbosa* almost pan-Canadian, as Scotty Creek is only about 100 km from the eastern edge of the Rocky Mountains. It appears unlikely that the species is a recent introduction at Scotty Creek, because the population was in an apparently undisturbed, natural habitat typical of the fens and laggs (wet transitional regions at the edge of ombrotrophic bogs) where it is found in the eastern part of its range (Sheviak and Catling 2003; Moisan and Pellerin 2013), and no introduced species were seen in its proximity.

FIGURE 2. Flower of *Arethusa bulbosa* L. (Dragon's-mouth, Orchidaceae) at Gracefield, Quebec, summer 2013. Photo: Marie-Ève Garon-Labrecque.

Arethusa bulbosa is not known to occur in Alberta; it is considered "critically imperilled" (S1) in Saskatchewan (Saskatchewan Conservation Data Centre 2014) and "imperilled" (S2) in Manitoba (Manitoba Conservation Data Centre 2014). In 2013, a single flowering stem was found at Scotty Creek, but it was also reported and collected in 2012 (*Fafard 111*, WLU!). Elsewhere in its range, the number of flowering individuals is known to vary greatly from one year to the next, and populations apparently do not flower every year (Moisan 2011), which makes estimation of the actual size of the population challenging. Although this is the only known occurrence in the NWT, focused surveys in rich fens and laggs in southern NWT should uncover other populations. In addition, potential threats to the habitat and population are limited because of the remoteness of the site at Scotty Creek. However, the apparently restricted range and population size of *A. bulbosa* in the NWT and the presence of a major disjunction suggest that it should be given the highest ranking ("may be at risk") in the territorial conservation status list (Working Group on General Status of NWT Species 2011).

Carex pauciflora, new to the NWT

Carex pauciflora Lightf. (Few-flowered Sedge, Cyperaceae) is reported as new to the NWT. It is morphologically similar to *Carex microglochin* Wahlenb., from which it is readily distinguished by its isolated culms on long rhizomes, its perigynium without a long rhachilla protruding from the perigynium (Figure 3), its pale-brown basal leaf sheaths, and the fact that it grows in the peat of lowland bogs (Cochrane 2002). Its distribution spans the Boreal Forest ecozone of North America and northern Europe, and it is known in all Canadian provinces and the Yukon Territory. Its occurrence at Scotty Creek fills an obvious gap in its known distribution.

Carex pauciflora is considered "secure" (S5) in British Columbia (B.C. Conservation Data Centre 2013) and Alberta (Alberta Environment and Sustainable Resource Development 2014). At least three distinct populations were found at Scotty Creek, the largest with about 1000 fruiting culms and the smallest with about 20 (potentially all from a single clone). Threats to habitat and populations are probably limited at Scotty Creek, and it is quite likely that further exploration of similar sites in southern boreal NWT or careful review of herbarium collections will result in the identification of additional populations. However, the fact that a single locality is currently known for *C. pauciflora* in the NWT suggests that it should be given the highest ranking ("may be at risk") in the territorial conservation status list (Working Group on General Status of NWT Species 2011), at least until its distribution and abundance in the NWT are better known.

FIGURE 3. Dense colony of *Carex pauciflora* Lightf. (Few-flowered Sedge, Cyperaceae) at Scotty Creek, Northwest Territories, summer 2013. Photo: Marie-Ève Garon-Labrecque.

Rumex britannica, a rare species at the northwestern edge of its range in the NWT

Rumex britannica L. (Greater Water Dock, Polygonaceae) was found in a fen adjacent to Goose Lake, dominated by *Equisetum fluviatile* L. (Water Horsetail), *Cicuta virosa* L. (Northern Water-hemlock), and *Scutellaria galericulata* var. *pubescens* Benth. It can easily be distinguished from the other *Rumex* species in the NWT by its basal rosette of leaves with a generally cordate base and more-or-less crispate margins, as well as its hermaphroditic flowers with the inner tepals entire and with distinct tubercles at maturity (Mosyakin 2005). The morphologically similar Eurasian *Rumex crispus* L. differs by having one tubercle distinctly larger than the other two on its inner tepals (all the same size in *R. britannica*), the tubercles aligned with or bulging below the base of the tepals (tubercles clearly above the base of the tepals in *R. britannica*), a distinct swollen joint on the flower pedicels (absent in *R. britannica*), and often more distinctly crispate leaves (Voss and Reznicek 2012). *Rumex crispus* has recently been reported as introduced in the vicinity of Yellowknife, but no vouchers were deposited in public herbaria and the record thus remains unconfirmed (Catling 2005a).

Rumex britannica was known in the NWT from a single specimen collected in 1971 near Buffalo Lake (60.133°N, 115.883°W), about 15 km north of the border with Alberta (*Ducruc 194-1*, QFA, DAO! [fragments and picture]). Porsild and Cody (1980) comment that the species "barely [enters] the district of Mackenzie between Ft. Smith and Hay River," the species being there at the northwesternmost edge of its range in North America (Mosyakin 2005). Examination of all *Rumex* specimens collected in the NWT in CAN, DAO, and MT revealed another specimen of *Rumex britannica*, which was collected from Dogface Lake (about 60.283°N, 119.083°W) in 1983 and originally identified as *Rumex occidentalis* S. Watson (*Moore 3*, MT!). Thus, the Scotty Creek population extends the known range of *Rumex britannica* about 160 km to the northwest from Dogface Lake.

Rare taxa and minor range extensions

Carex brunnescens subsp. *sphaerostachya* (Round-spike Brownish Sedge, Cyperaceae) was collected in a wet open depression of a *Betula* thicket at Scotty Creek. Although the species is found throughout northern North America and Eurasia, subspecies *sphaerostachya* is considered to be restricted to Europe and eastern North America east of Saskatchewan (Toivonen 2002). The collection at Scotty Creek, therefore, confirms the presence of this subspecies in the NWT and also appears to be a significant extension to the northwest of the known range of the subspecies. However, Toivonen (2002) also indicates that intergradation with the widespread *C. brunnescens* (Pers.) Poir. subsp. *brunnescens* (Brownish Sedge) in the west makes it hard to draw a clear boundary on the distribution of *C. brunnescens* subsp. *sphaerostachya*. Although some rare specimens appear to combine the characteristics of the two subspecies, specimens of subspecies *sphaerostachya* are generally distinct by the absence of papillae on the abaxial surface of the narrow leaves, which are generally less than 1.7 mm in width, and by the wide separation of the two distal-most spikes of the inflorescence exposing the male portion of the clavate terminal spike (Cayouette in prep.). In contrast, subspecies *brunnescens* has abundant papillae on the wide leaves (1.4–2.5 mm wide) and congested distal spikes hiding the male portion of the terminal spike. The two subspecies also differ in ecology: subspecies *brunnescens* is normally found in drier habitats in the open, whereas subspecies *sphaerostachya* apparently prefers wetter, closed habitats (Cayouette in prep.). These differences might indicate that the variation is eco-phenotypic in nature, and *C. brunnescens* is in need of a thorough, worldwide taxonomic revision (Toivonen 2002; Cayouette in prep.). Nevertheless, these characters separate the species into two groups with very few intermediates in the eastern part of the species' range, and they also appear to work well on the majority of western Canadian specimens examined, including the Scotty Creek collections. MT and CAN herbarium specimens from as far west as Alberta and the NWT could be unambiguously assigned to *C. brunnescens* subsp. *sphaerostachya* based on the above characters. More study is needed to determine the precise distribution of the two subspecies in the northwest and whether subspecies *sphaerostachya* might represent a rare taxon in the flora of the NWT.

Carex heleonastes L. f. (Hudson Bay Sedge, Cyperaceae) was collected in a fen at Scotty Creek. It has apparently not been collected in the NWT since 1977 (*Cairns 1136*, DAO [specimen not found]; Environment and Natural Resources 2014) and is considered "sensitive" (Working Group on General Status of NWT Species 2011). *C. heleonastes* has a (quasi-) circumpolar distribution, but it is rare or sporadic throughout North America, where it tends to occur in open calcareous wetlands such as fens (Shackleford 2004).

Carex livida (Wahlenb.) Willd. (Livid Sedge, Cyperaceae) was seen in a rich fen at Scotty Creek. This is the fifth specimen known from the NWT, filling a gap between the populations at Heart Lake (*Talbot 2305*, ALTA!), on Ebutt Hills, 70 km northwest of Fort Simpson (*Reid 1344*, ALTA!), and in Nahanni National Park (Bennett 2013; Environment and Natural Resources 2014). *C. livida* is a (quasi-)circumpolar entity that is distributed from beyond the tree line south to Panama in America, but is more or less rare and sporadic throughout its range (Rothrock and Reznicek 2002).

Epilobium leptophyllum Raf. (Bog Willowherb, Onagraceae) was seen in many wet bogs and marshes at Scotty Creek. It is considered "sensitive" and relatively rare in the NWT (Working Group on General Status of NWT Species 2011), but appears locally common in the boreal plains south of Fort Simpson and west of Great Slave Lake where it was collected at many localities (Cody *et al.* 2003; Environment and Natural Resources 2014).

Juncus stygius subsp. *americanus* (Bucheneau) Húlten (American Moor Rush, Juncaceae) was collected for the fifth time in the NWT in a rich bog of Scotty Creek. It lies only about 30 km southwest of another known locality (*Kershaw s.n.*, 3-VIII-2002, DAO!; Cody and Reading 2005). It is considered "sensitive" in the NWT (Working Group on General Status of NWT Species 2011), although its distribution is broad: from 60.7°N to beyond the tree limit at 69.2°N in the Mackenzie River Valley (Environment and Natural Resources 2014). More sampling in the wet bogs, fens, and marshes where it dwells is needed in the NWT.

Lycopus uniflorus Michx. (Northern Water-horehound, Lamiaceae) was collected on the shore of Goose Lake in an *Equisetum fluviatile*-dominated marsh. It is relatively rare in the NWT and has not been assessed by the Working Group on General Status of NWT Species (2011). *L. uniflorus* has been collected in a few sites in the southern boreal plain south of Great Slave Lake from 110°W to 123°W, as well as along the Mackenzie up to 66°N (Environment and Natural Resources 2014). The Scotty Creek population, therefore, lies approximately in the centre of its known range in the NWT.

Malaxis monophyllos var. *brachypoda* (A. Gray) F. Morris & E. A. Eames (North American White Adder's-mouth, Orchidaceae) was collected for the second time in the NWT in a rich riparian fen along the shore of First Lake (Figure 4). The population at Scotty Creek fills the gap between the closest record at Liard Hotsprings in northern British Columbia (59.4°N, 126.083°W) and the only other record in the NWT, in a swampy area around Yellowknife (Cody and Johnston 2003). The species is ranked as "may be at risk" in the NWT (Working Group on General Status of NWT Species 2011).

Najas flexilis (Willd.) Rostk. & W. L. E. Schmidt (Slender Naiad, Hydrocharitaceae) was found in shallow water near the shore of First Lake. This is the second locality for the species in the NWT; the other is an unnamed lake about 210 km to the north along the Mackenzie River (62.98°N, 123.18°W; *Kershaw 14*, DAO!; Cody and Reading 2005). The Scotty Creek specimen fills the gap between the other NWT locality and the closest records in southern Yukon (60.11°N, 128.80°W; Cody *et al.* 2005) and northern Alberta (about 59.5°N, 113.2°W; Moss 1983). It is considered "sensitive" in the NWT (Working Group on General Status of NWT Species 2011), but a higher ranking should be considered given the limited number of specimens and restricted range of the species in the NWT and adjacent Yukon.

Neottia cordata (L.) Rich. (Heart-leaved Twayblade, Orchidaceae) was collected in a rich peat plateau shaded by tall black spruce trees (Figure 5). The Scotty Creek population extends the known range of this spe-

FIGURE 4. Fresh specimen of *Malaxis monophyllos* var. *brachypoda* (A. Gray) F. Morris & E. A. Eames (North American White Adder's-mouth, Orchidaceae), collected at Scotty Creek, Northwest Territories, summer 2013. Photo: Marie-Ève Garon-Labrecque.

cies about 320 km to the east, and this is also the only known site for this species outside the Mackenzie Mountains in the NWT. The closest localities are in the Hole-in-the-Wall Lake area, Nahanni National Park (61.8°N, 127.3°W), where the species was collected by Talbot in 1976 (*Talbot 6011-2* & *6184-X*, DAO!) and by Line in 2000 (*Line 2000-356*, DAO!; Environment and Natural Resources 2014). The only other known report

FIGURE 5. Inflorescence of *Neottia cordata* (L.) Rich. (Heart-leaved Twayblade, Orchidaceae) at Scotty Creek, Northwest Territories, summer 2013. Photo: Marie-Ève Garon-Labrecque.

in the NWT is more than 50 years old and 200 km north in the Mackenzie Mountains, about 63.7°N, 127.6°W (*Jeffrey 422*, DAO!; Environment and Natural Resources 2014). *N. cordata* is considered "sensitive" in the NWT (Working Group on General Status of NWT Species 2011).

Nymphaea tetragona Georgi (Pygmy Water-lily, Nymphaeaceae) was collected in Goose Lake. It is known in the NWT from a few other lakes and ponds from Fort Smith to Yellowknife and south, the closest collection being only about 40 km north of Scotty Creek (Catling 2005b). It is considered "sensitive" in the NWT (Working Group on General Status of NWT Species 2011).

Pedicularis parviflora Sm. (Small-flowered Lousewort, Orobanchaceae) was seen in several rich fens and wet bogs at Scotty Creek. It is ranked as "sensitive" in the NWT (Working Group on General Status of NWT Species 2011) and has been collected mainly in the southern boreal plains of the NWT, although it is found to at least 65°N (Environment and Natural Resources 2014).

Platanthera dilatata (Pursh) Lindl. ex L. C. Beck var. *dilatata* (Tall White Bog Orchid, Orchidaceae) was collected in an open marshy fen at Scotty Creek. It is ranked as "may be at risk" (Working Group on General Status of NWT Species 2011); the only other known locations for the species in the NWT are in Nahanni National Park (*Talbot s.n.*, 6-VII-1976, DAO!; *Scotter 24227*, DAO!) and Tungsten (*Spicer 1501*, DAO!), both in the Mackenzie Mountains (Environment and Natural Resources 2014). The Scotty Creek collection constitutes a small range extension (about 320 km) to the east of the western portion of the range of this Cordilleran–Eastern American disjunct species, which is known only along the Pacific Coast Ranges and the Rocky Mountains in the west and from Newfoundland to central Manitoba south to Indiana in the east, with no records known in Nunavut and Saskatchewan (Sheviak 2003). Scotty Creek is, therefore, probably near the northeastern limit of the species' range in western North America.

Potamogeton natans L. (Floating Pondweed, Potamogetonaceae) was collected in the water close to the shore of First Lake. It is ranked "sensitive" in the NWT (Working Group on General Status of NWT Species, 2011) and is known from around Yellowknife west to the Nahanni National Park in the NWT (Environment and Natural Resources 2014).

Rhynchospora alba (L.) Vahl (White Beakrush, Cyperaceae) was collected for the third time in the NWT in a wet fen at Scotty Creek. The closest report of the species is only about 80 km to the north, north of Fort Simpson (62°N, 121.5°W; *Kershaw 20*, DAO!; Cody and Reading 2005). The only other specimen known in the NWT is about 245 km to the west, in a wet fen around Mile 92 of Mackenzie Highway (*Talbot 3701*, DAO!; Environment and Natural Resources 2014). Because of its apparent rarity, it is ranked "may be at risk" in the NWT (Working Group on General Status of NWT Species 2011), but further exploration of rich fens and bogs in the southern NWT should uncover other populations.

Utricularia minor L. (Lesser Bladderwort, Lentibulariaceae) was seen in lakes and small bog depressions at Scotty Creek. It is ranked "sensitive" in the NWT (Working Group on General Status of NWT Species 2011) and has been collected mainly around Yellowknife and in Nahanni National Park (Bennett 2013), but also once at the apex of McTavish Arm, Great Bear Lake (66.5°N; Environment and Natural Resources 2014).

Lime-indicator species

A total of 48 taxa (34%) found at Scotty Creek are reported in the literature as indicators of alkaline or mineral-rich soil or water (Table 1). The presence of many calciphiles (lime-loving plants) in this peatland-dominated landscape may be explained by the presence of a significant amount of calcium and magnesium in the water of the lakes and downstream fens and marshes of Scotty Creek (Hayashi *et al.* 2004). Although the site is almost uniformly covered by organic deposits up to 8 m deep, a small till/glacio-fluvial complex east of Goose Lake (Duk-Rodkin 2011) might include larger alkaline rocks which could be partly responsible for the presence of alkaline minerals in the surface water. However, a potentially more important source of alkaline minerals is the deeply buried glacio-lacustrine clay layer found almost throughout the site. This mineral layer is highly reactive to hydrochloric acid (M.-E. G.-L., personal observation), which indicates accumulation of carbonates, a phenomenon that has been documented in other deep glacio-lacustrine sediments of the Taiga Plain (Macdonald 1987a). The source of these carbonates is not known with certainty, but the region is underlain by a limestone-rich Devonian sedimentary bedrock (Geological Survey of Canada 1957) and the carbonates might have been deposited early during the last deglaciation by the inflow of calcium-rich waters draining from calcareous glacial deposits (MacDonald 1987b). Hayashi *et al.* (2004) have shown that the deeply buried clay of Scotty Creek contains mineral-rich groundwater that very slowly discharges into the peat and surface waters.

Beavers appear to play a certain role in the growth of lime indicators at Scotty Creek. For instance, calcicolous plants such as *Malaxis monophyllos* var. *brachypoda*, *Pedicularis parviflora*, and *Carex chordorrhiza* Ehrh. ex L. f. (Creeping Sedge) were all found in beaver feeding and nesting areas. In addition, peaks in the richness of calcicolous plants near lake shores could often be correlated with beaver activity. This is probably due to the fact that beavers dig channels to transport their food (Link 2004) and, doing so, they might transport some of the buried minerals near the ground surface, thus potentially enriching the soil available to plant roots. The effect of beaver activity on plants could also be seen in the presence of indicators of disturbed mineral soil, such as *Chamerion angustifolium* (L.) Holub subsp. *angustifolium* (Fireweed), *Potentilla norvegica* L. (Rough Cinquefoil), and *Urtica dioica*

TABLE 1. Calciphiles collected at Scotty Creek. A taxon is considered "calciphile" when reported: **1**, on calcareous, alkaline, rich or mineral substrate in continental Nunavut and Northwest Territories (Porsild and Cody 1980); **2**, mostly found in lakes with at least 48.9 mg HCO_3^-/L in New England (Hellquist 1980); **3**, typical of extreme-rich fens in Alberta (Vitt and Chee 1990); **4**, prominent or common only on basic substrates in Northwest Territories (Timoney *et al.* 1993); **5**, preferring minerotrophic peatlands in Quebec (Garneau 2001); **6**, preferring rich fens in Canada (Gignac *et al.* 2004); **7**, calcicolous or calciphilous in northern Quebec (Dignard 2007); **8**, having an affinity for calcareous substrates in northern Quebec (Dignard 2011).

Taxon	References
Alnus incana subsp. *tenuifolia*	5
Andromeda polifolia	5
Arctous rubra	7
Calamagrostis canadensis var. *canadensis*	5
Calamagrostis stricta subsp. *inexpensa*	7
Carex aquatilis var. *aquatilis*	5,6
Carex canescens subsp. *canescens*	5
Carex capillaris subsp. *capillaris*	1,3,7,8
Carex chordorrhiza	5,6,7
Carex diandra	5,6
Carex disperma	6
Carex gynocrates	1,5,7,8
Carex leptalea	1,5,6
Carex livida	1,5,7
Carex magellanica subsp. *irrigua*	1,5
Carex rostrata	5
Carex tenuiflora	1,5,6
Carex vaginata	1,4,5,6,7,8
Comarum palustre	5
Coptidium lapponicum	5
Dasiphora fruticosa	4,5
Drosera anglica	1,3,5
Eriophorum angustifolium subsp. *angustifolium*	4,5
Eriophorum gracile subsp. *gracile*	5,6
Eriophorum viridicarinatum	1,5
Galearis rotundifolia	1,5
Galium labradoricum	5
Juncus stygius subsp. *americanus*	5
Larix laricina	1
Maianthemum trifolium	5
Malaxis monophyllos var. *brachypoda*	1
Menyanthes trifoliata	5
Myrica gale	5
Parnassia palustris	1,3
Pinguicula villosa	5
Potamogeton praelongus	2
Potamogeton richardsonii	2
Rhynchospora alba	1
Rubus arcticus subsp. *acaulis*	5
Salix pedicellaris	5
Shepherdia canadensis	1
Triantha glutinosa	1,3
Trichophorum alpinum	1,3,5,6
Trichophorum cespitosum	1,3
Triglochin maritima	1,5
Utricularia intermedia	5
Utricularia minor	5
Urtica dioica subsp. *gracilis*	1

subsp. *gracilis* (Aiton) Selander (Slender Stinging Nettle) on top of and around beaver lodges (Porsild and Cody 1980; Carey 1995).

Annotated species list

The geographic coordinates of only one representative specimen of each species are given when more than one has been collected. A general description of the habitat is given when a species was found in many different localities at Scotty Creek. Specimen citations comprise only the first collector's name, collection number, and herbarium acronym.

Lycophytes

LYCOPODIACEAE

Diphasiastrum complanatum (L.) Holub — Fafard 22 (WLU), Garon-Labrecque 13-087 (MT). SCOTTY CREEK, NWT, 61.301°N, 121.310°W. With *Cladonia* spp. in a wet depression of a shrubby birch stand. Circumpolar.

Lycopodium annotinum L. — Garon-Labrecque 13-019 (MT). SCOTTY CREEK, NWT, 61.301°N, 121.310°W. Peat plateau dominated by *Picea mariana* and *Cladonia* spp. Circumpolar.

Monilophytes

EQUISETACEAE

Equisetum arvense L. — Garon-Labrecque 13-082 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.293°W. Peat plateau with tall *Picea mariana*, *Orthilia secunda* on the ground, and dense cover of *Hylocomium splendens* and *Pleurozium schreberi*. Circumpolar.

Equisetum fluviatile L. — Garon-Labrecque 13-041 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Dominant on the shore of Goose Lake, with *Lycopus uniflorus*. Circumpolar.

Equisetum scirpoides Michx. — Garon-Labrecque 13-032 (MT). SCOTTY CREEK, NWT, 61.298°N, 121.299°W. Peat plateau in partial shade under *Picea mariana*, with *Rhododendron groenlandicum*. Circumpolar.

Equisetum sylvaticum L. — Garon-Labrecque 13-083 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.293°W. Peat plateau, with tall *Picea mariana*, *Orthilia secunda* and feathermosses. Circumpolar.

Gymnosperms

CUPRESSACEAE

Juniperus communis var. *depressa* Pursh — Garon-Labrecque 13-222 (MT). SCOTTY CREEK, NWT, 61.298°N, 121.299°W. Sandy hill with *Picea mariana*, *Pinus banksiana*, *Geocaulon lividum*, *Rosa acicularis*, and *Cladonia* spp. Widespread North American.

PINACEAE

Larix laricina (Du Roi) K. Koch — Garon-Labrecque 13-103 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.293°W. Sandy hill with *Picea mariana*, *Pinus* *banksiana*, *Geocaulon lividum*, *Rosa acicularis*, and *Cladonia* spp. Widespread North American.

Picea glauca (Moench) Voss — Garon-Labrecque 13-197 (MT). SCOTTY CREEK, NWT, 61.312°N, 121.290°W. Peat plateau dominated by *Picea mariana*, *Rhododendron groenlandicum*, and *Hylocomium splendens*. Widespread North American.

Picea mariana (Mill.) Britton, Sterns & Poggenb. — Garon-Labrecque 13-005 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.306°W. Peat plateau with *Rhododendron groenlandicum*, *Rubus chamaemorus*, and *Cladonia* spp. Widespread North American.

Pinus banksiana Lamb. — Garon-Labrecque 13-201 (MT). SCOTTY CREEK, NWT, 61.297°N, 121.303°W. Peat plateau with *Rubus chamaemorus* and *Carex* spp. Widespread North American.

NYMPHAEACEAE

Nuphar variegata Durand — Garon-Labrecque 13-094 (MT). SCOTTY CREEK, NWT, 61.292°N, 121.288°W. Shallow, dark water near the shore of Goose Lake, pH near neutral. Widespread North American.

Nymphaea tetragona Georgi — Garon-Labrecque 13-065 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.297°W. Shallow, dark water near the shore of Goose Lake, pH near neutral. Circumpolar.

Monocots

CYPERACEAE

Carex aquatilis Wahlenb. var. *aquatilis* — Garon-Labrecque 13-073, 13-075, 13-134, 13-135 (MT). SCOTTY CREEK, NWT, 61.304°N, 121.303°W. In various habitats, mostly in wet open areas forming colonies, very common. Circumpolar.

Carex aurea Nutt. — Garon-Labrecque 13-104 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Edge of *Sphagnum* hummock, in a semi-closed fen under *Larix laricina*. Widespread North American.

Carex brunnescens subsp. *sphaerostachya* (Tuck.) Kalela — Garon-Labrecque 13-088 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.301°W. Wet depression, in the opening of a *Betula glandulosa* thicket with lycopods and *Cladonia* spp. Eastern North American.

Carex canescens L. subsp. *canescens* — Garon-Labrecque 13-053, 13-132 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Marshy fens with *Carex aquatilis* var. *aquatilis* and other sedges, often with *Utricularia intermedia*. Circumpolar.

Carex capillaris L. subsp. *capillaris* — Garon-Labrecque 13-107 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Peat plateaus with *Picea mariana*, *Vaccinium vitis-idaea*, *Vaccinium oxycoccos*, and *Sphagnum* spp. Circumpolar.

Carex chordorrhiza Ehrh. ex L. f. — Fafard 6 (WLU), Garon-Labrecque 13-020, 13-086, 13-133 (MT). SCOTTY CREEK, NWT, 61.304°N, 121.303°W. Fens and bogs, running on *Sphagnum*, with other *Carex* spp. Circumpolar.

Carex diandra Schrank — Fafard 33 (WLU), Garon-Labrecque 13-072 (MT). SCOTTY CREEK, NWT, 61.304°N, 121.303°W. Edge of *Sphagnum* hummock, in a rich open bog with *Drosera anglica*, *Sarracenia purpurea*, *Larix laricina*, and *Carex magellanica* subsp. *irrigua*. Circumpolar.

Carex disperma Dewey — Garon-Labrecque 13-102, 13-124, 13-125, 13-157 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.290°W. Open bogs, top and edge of *Sphagnum* hummocks. Circumpolar.

Carex gynocrates Wormsk. ex Drejer — Garon-Labrecque 13-092, 13-093, 13-108A, 13-122 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Peat plateaus; shade species found under *Picea mariana*, often with *Pleurozium schreberi*. Circumpolar.

Carex heleonastes L. f. — Garon-Labrecque 13-076 (MT). SCOTTY CREEK, NWT, 61.306°N, 121.295°W. Fen, intermixed in a *Carex aquatilis* var. *aquatilis* stand, with *Drosera rotundifolia*, *Maianthemum trifolium*, *Larix laricina*, and *Platanthera dilatata* var. *dilatata*. Circumpolar.

Carex leptalea Wahlenb. — Garon-Labrecque 13-051, 13-108B, 13-195 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Mostly in open areas associated with various species, such as *Rhododendron groenlandicum*, *Vaccinium vitis-idaea*, *Vaccinium oxycoccos*, and *Geocaulon lividum*. Widespread North American.

Carex limosa L. — Garon-Labrecque 13-022 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Marshy areas with *Menyanthes trifoliata*, *Calla palustris*, and *Betula glandulosa*. Circumpolar.

Carex livida (Wahlenb.) Willd. — Garon-Labrecque 13-181 (MT). SCOTTY CREEK, NWT, 61.301°N, 121.296°W. Open *Sphagnum* fen with *Carex limosa*, *Maianthemum trifolium*, and *Sarracenia purpurea*. Circumpolar.

Carex magellanica subsp. *irrigua* (Wahlenb.) Hiitonen — Garon-Labrecque 13-021, 13-023, 13-136 (MT). SCOTTY CREEK, NWT, 61.306°N, 121.293°W. Bogs and fens, with *Eriophorum* spp., *Maianthemum trifolium*, *Chamaedaphne calyculata*, and *Menyanthes trifoliata*. Circumpolar.

Carex pauciflora Lightf. — Garon-Labrecque 13-172, 13-200, 13-300 (MT). SCOTTY CREEK, NWT, 61.302°N, 121.305°W. Rich *Sphagnum* bogs with *Sarracenia purpurea*, *Larix laricina*, *Drosera anglica*, and *Triantha glutinosa*. Circumpolar.

Carex rostrata Stokes — Fafard 38 (WLU), Garon-Labrecque 13-044, 13-061, 13-155, 13-170 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Margins of lakes and fens, often with other sedges, *Menyanthes trifoliata*, *Maianthemum trifolium*, *Calla palustris*, and *Typha latifolia*. Circumpolar.

Carex tenuiflora Wahlenb. — Garon-Labrecque 13-080, 13-085, 13-089, 13-158 (MT). SCOTTY CREEK, NWT, 61.300°N, 121.299°W. Open fens with

Menyanthes trifoliata, *Carex* spp., *Comarum palustre*, and *Maianthemum trifolium*. Circumpolar.

Carex vaginata Tausch — Garon-Labrecque 13-091, 13-105, 13-115 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Uncommon on peat plateaus under partial shade with *Picea mariana*, *Equisetum scirpoides*, *Larix laricina*, *Rhododendron groenlandicum*, *Equisetum sylvaticum*, *Vaccinium vitis-idaea*, *Vaccinium oxycoccos*, and *Pleurozium schreberi*. Circumpolar.

Eriophorum angustifolium Honck. subsp. *angustifolium* — Garon-Labrecque 13-114 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.289°W. Peat plateau with *Picea mariana*, *Vaccinium vitis-idaea*, and *Vaccinium oxycoccos*. Circumpolar.

Eriophorum gracile W. D. J. Koch ex A. Roth subsp. *gracile* — Garon-Labrecque 13-161 (MT). SCOTTY CREEK, NWT, 61.302°N, 121.304°W. Open *Sphagnum* bog with *Rhododendron groenlandicum* and *Rubus chamaemorus*. Circumpolar.

Eriophorum russeolum subsp. *albidum* (F. Nyl.) Väre — Garon-Labrecque 13-010A, 13-010B, 13-012, 13-131, 13-154 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.304°W. Open bogs, very common species growing with *Sarracenia purpurea*, *Larix laricina*, *Drosera rotundifolia*, *Drosera anglica*, *Maianthemum trifolium*, *Carex* spp., *Scheuchzeria palustris*, *Andromeda polifolia*, and *Chamaedaphne calyculata*. Circumpolar.

Eriophorum vaginatum L. subsp. *vaginatum* — Fafard 19 (WLU), Garon-Labrecque 13-042, 13-160 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Open fens and bogs, with *Equisetum fluviatile*, *Lycopus uniflorus*, *Rhododendron groenlandicum*, and *Rubus chamaemorus*. Circumpolar.

Eriophorum viridicarinatum (Engelm.) Fernald — Fafard 8 (WLU), Garon-Labrecque 13-038 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Rich fen with *Larix laricina*, *Arethusa bulbosa*, *Triglochin maritima*, *Pedicularis parviflora*, and *Platanthera aquilonis*. Widespread North American.

Rhynchospora alba (L.) Vahl — Garon-Labrecque 13-141 (MT). SCOTTY CREEK, NWT, 61.300°N, 121.302°W. Rich wet fen with *Drosera anglica*, *Sarracenia purpurea*, *Larix laricina*, and *Carex magellanica* subsp. *irrigua*. Circumpolar.

Schoenoplectus acutus (Muhl. ex Bigelow) Á. Löve & D. Löve — Garon-Labrecque 13-066, 13-184 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.297°W. Sandy soil mixed with dark organic matter in the littoral zone of Goose Lake, water pH near neutral, with *Nymphaea tetragona* and *Potamogeton* spp. Widespread North American.

Trichophorum alpinum (L.) Pers. — Garon-Labrecque 13-036, 13-081, 13-130, 13-153 (MT). SCOTTY CREEK, NWT, 61.303°N, 121.279°W. Rich open bogs with *Drosera anglica*, *Drosera rotundifolia*, *Sarracenia purpurea*, *Larix laricina*, *Maianthemum trifolium*, *Carex magellanica* subsp. *irrigua*, and sometimes with *Trichophorum cespitosum*. Circumpolar.

Trichophorum cespitosum (L.) Hartm. — Garon-Labrecque 13-129, 13-143 (MT). SCOTTY CREEK, NWT, 61.301°N, 121.293°W. Uncommon in rich bogs with *Sarracenia purpurea*, *Larix laricina*, *Trichophorum alpinum*, *Drosera anglica*, and *Carex magellanica* subsp. *irrigua*. Circumpolar.

JUNCACEAE

Juncus stygius subsp. *americanus* (Buchenau) Hultén — Garon-Labrecque 13-039 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Rich bog with *Larix laricina*, *Arethusa bulbosa*, *Triglochin maritima*, *Pedicularis parviflora*, and *Platanthera aquilonis*. Widespread North American.

JUNCAGINACEAE

Triglochin maritima L. — Garon-Labrecque 13-029 (MT). SCOTTY CREEK, NWT, 61.304°N, 121.303°W. Open marshy area with *Menyanthes trifoliata*, *Larix laricina*, and *Sphagnum* spp. Circumpolar.

ORCHIDACEAE

Arethusa bulbosa L. — Fafard 111 (WLU), Garon-Labrecque 13-034 (MT). SCOTTY CREEK, NWT, 61.303°N, 121.279°W. Rich fen with *Larix laricina*, *Drosera anglica*, *Triantha glutinosa*, *Triglochin maritima*, *Pedicularis parviflora*, and *Platanthera aquilonis*. Eastern North American.

Galearis rotundifolia (Banks ex Pursh) R.M. Bateman — Garon-Labrecque 13-120 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.288°W. Peat plateau, in moss under *Picea mariana*, with *Pyrola asarifolia* subsp. *asarifolia*. Eastern North American.

Goodyera repens (L.) R. Br. — Garon-Labrecque 13-202 (MT). SCOTTY CREEK, NWT, 61.297°N, 121.303°W. Sandy hill with tall *Pinus banksiana*, *Equisetum scirpoides*, *Cornus canadensis*, and *Alnus viridis* subsp. *crispa*. Widespread North American.

Malaxis monophyllos var. *brachypoda* (A. Gray) F. Morris & E. A. Eames — Garon-Labrecque 13-140 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Shore of First Lake near a beaver lodge. Rich fen, in the shade of *Menyanthes trifoliata*, with peat and moss, *Pedicularis parviflora*, and *Comarum palustre*. Widespread North American.

Neottia cordata (L.) Rich. — Garon-Labrecque 13-148 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.292°W. Peat plateau dominated by *Picea mariana* and *Pleurozium schreberi*, with *Equisetum scirpoides*, *Larix laricina*, *Rhododendron groenlandicum*, and *Equisetum sylvaticum*. Circumpolar.

Platanthera aquilonis Sheviak — Garon-Labrecque 13-033, 13-106 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Found in a variety of rich wet habitats. Widespread North American.

Platanthera dilatata (Pursh) Lindl. ex L. C. Beck var. *dilatata* — Garon-Labrecque 13-223 (MT). SCOTTY

CREEK, NWT, 61.308°N, 121.307°W. Open fen, at the base of a *Sphagnum* hummock with *Maianthemum trifolium*, *Carex limosa*, and *C. aquatilis* var. *aquatilis*. Widespread North American.

Spiranthes romanzoffiana Cham. — Garon-Labrecque 13-049, 13-142, 13-224 (MT). SCOTTY CREEK, NWT, 61.316°N, 121.300°W. Generally in rich bogs with *Scheuchzeria palustris*, *Drosera anglica*, and *Sarracenia purpurea*. Widespread North American.

POACEAE

Arctagrostis latifolia subsp. *arundinacea* (Trin.) Tzvelev — Garon-Labrecque 13-193, 13-194 (MT). SCOTTY CREEK, NWT, 61.312°N, 121.292°W. Opening of a forest, dominated by *Picea mariana*, *Petasites frigidus* var. *sagittatus*, *Rhododendron groenlandicum*, *Hylocomium splendens*, and *Equisetum sylvaticum*. Amphi-Beringian.

Calamagrostis canadensis (Michx.) P. Beauv. var. *canadensis* — Garon-Labrecque 13-026 (MT). SCOTTY CREEK, NWT, 61.307°N, 121.302°W. Margin of a bog and a peat plateau, semi-shaded, with *Rhododendron groenlandicum* and *Betula glandulosa*. Circumpolar.

Calamagrostis stricta subsp. *inexpensa* (A. Gray) C. W. Greene — Garon-Labrecque 13-025 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.301°W. Opening of *Betula glandulosa* stand. Widespread North American.

POTAMOGETONACEAE

Potamogeton alpinus Balb. — Garon-Labrecque 13-057 (MT). SCOTTY CREEK, NWT, 61.307°N, 121.307°W. Water of a marsh, under the shade of *Sparganium natans*, *Menyanthes trifoliata*, and *Lysimachia thyrsiflora*. Circumpolar.

Potamogeton cf. *pusillus* subsp. *tenuissimus* (Mert. & W. D. J. Koch) R. R. Haynes & Hellq. — Garon-Labrecque 13-067, 13-099, 13-162 (MT). SCOTTY CREEK, NWT, 61.307°N, 121.307°W. Shallow water of First Lake, with *Utricularia vulgaris* and *Nuphar variegata*. Circumpolar. No flowering individual was encountered and the sterile specimens could not be identified with certainty. It could also correspond to *Potamogeton obtusifolius* Mert. & W. D. J. Koch.

Potamogeton gramineus L. — Garon-Labrecque 13-077, 13-079 (MT). SCOTTY CREEK, NWT, 61.297°N, 121.298°W. Dark water of the littoral zone of Goose Lake, with *Schoenoplectus acutus*, pH near neutral. Circumpolar.

Potamogeton natans L. — Garon-Labrecque 13-186 (MT). SCOTTY CREEK, NWT, 61.304°N, 121.305°W. Shallow water of First Lake, pH near neutral. Circumpolar.

Potamogeton praelongus Wulfén. — Garon-Labrecque 13-095, 13-096 (MT). SCOTTY CREEK, NWT, 61.294°N, 121.301°W. Dark, shallow water of Goose Lake, pH near neutral. Circumpolar.

Potamogeton richardsonii (A. Benn.) Rydb. — Garon-Labrecque 13-098, 13-175, 13-185 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.292°W. Dark, shallow water of Goose Lake, pH near neutral. Widespread North American.

TOFIELDIACEAE

Triantha glutinosa (Michx.) Baker Garon-Labrecque 13-035, 13-209 (MT). SCOTTY CREEK, NWT, 61.303°N, 121.279°W. Rich fens and bogs with *Sarracenia purpurea* and *Drosera anglica*. Circumpolar.

Eudicots

ADOXACEAE

Viburnum edule (Michx.) Raf. — Garon-Labrecque 13-159 (MT). SCOTTY CREEK, NWT, 61.298°N, 121.297°W. Under *Picea mariana* stand near Goose Lake shore, with *Alnus incana* subsp. *tenuifolia*. Widespread North American.

APIACEAE

Cicuta bulbifera L. — Garon-Labrecque 13-069 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.298°W. In an *Equisetum fluviatile* marsh on Goose Lake. Widespread North American.

Cicuta virosa L. — Garon-Labrecque 13-126 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.297°W. Fen, under the shade of *Menyanthes trifoliata*. Circumpolar.

ARACEAE

Calla palustris L. — Garon-Labrecque 13-187, 13-188 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.310°W. Marshy fen with *Menyanthes trifoliata*, *Carex rostrata*, *Carex limosa*, and *Carex magellanica* subsp. *irrigua*. Circumpolar.

ASPARAGACEAE

Maianthemum trifolium (L.) Sloboda — Garon-Labrecque 13-006 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.304°W. Bog with *Picea mariana*, *Andromeda polifolia*, *Chamaedaphne calyculata*, *Drosera rotundifolia*, and *Carex* spp. East Asian–North American.

ASTERACEAE

Erigeron elatus (Hook.) Greene — Garon-Labrecque 13-113 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. On top of a dry *Sphagnum* hummock with *Larix laricina* and *Picea mariana*. Widespread North American.

Petasites frigidus (L.) Fr. var. *frigidus* — Garon-Labrecque 13-116 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.289°W. Peat plateau with *Picea mariana*, *Sphagnum* spp., *Vaccinium vitis-idaea*, and *Vaccinium oxycoccos*. Circumpolar.

Petasites frigidus var. *sagittatus* (Pursh) Cherniawsky — Garon-Labrecque 13-156 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.293°W. Open wet bog with *Salix* spp. and *Chamaedaphne calyculata*. Widespread North American.

BETULACEAE

Alnus incana subsp. *tenuifolia* (Nutt.) Breitung — Garon-Labrecque 13-220 (MT). Scotty Creek, NWT, 61.298°N, 121.297°W. Open sandy area close to Goose Lake. Widespread North American.

Alnus viridis subsp. *crispa* (Aiton) Turrill — Garon-Labrecque 13-117, 13-199 (MT). Scotty Creek, NWT, 61.310°N, 121.288°W. Dry peat plateaus and sandy hills under shade. East Asian–North American.

Betula glandulosa Michx. — Garon-Labrecque 13-024, 13-165, 13-177, 13-178, 13-179, 13-210 (MT). Scotty Creek, NWT, 61.310°N, 121.288°W. Ubiquitous on the site in shrubby areas. Widespread North American.

Betula neoalaskana Sarg. — Garon-Labrecque 13-064, 13-118, 13-221 (MT). Scotty Creek, NWT, 61.302°N, 121.305°W. Frequent on peat plateaus. Western American.

CAPRIFOLIACEAE

Linnaea borealis L. — Garon-Labrecque 13-203 (MT). Scotty Creek, NWT, 61.303°N, 121.297°W. Sandy hill with tall *Pinus banksiana*, *Equisetum scirpoides*, *Cornus canadensis*, and *Alnus viridis* subsp. *crispa*. Circumpolar.

CARYOPHYLLACEAE

Stellaria borealis Bigelow subsp. *borealis* — Garon-Labrecque 13-214 (MT). Scotty Creek, NWT, 61.303°N, 121.297°W. On *Sphagnum* hummock under the shade of *Picea mariana* and *Larix laricina*, with *Rhododendron groenlandicum*, *Vaccinium uliginosum*. and *Chamaedaphne calyculata*. Circumpolar.

Stellaria longipes Goldie subsp. *longipes* — Garon-Labrecque 13-046 (MT). Scotty Creek, NWT, 61.303°N, 121.297°W. In an open wet marshy fen with *Carex rostrata* and *Menyanthes trifoliata*. Circumpolar.

CELASTRACEAE

Parnassia palustris L. — Garon-Labrecque 13-119, 13-168, 13-189 (MT). Scotty Creek, NWT, 61.297°N, 121.297°W. Rich open peat plateaus with *Larix laricina*, *Sphagnum* spp., and *Rubus chamaemorus*. Widespread North American.

CORNACEAE

Cornus canadensis L. — Garon-Labrecque 13-204 (MT). Scotty Creek, NWT, 61.297°N, 121.303°W. Sandy hill with *Pinus banksiana*, *Equisetum scirpoides*, and *Alnus viridis* subsp. *crispa*. Widespread North American.

Cornus stolonifera Michx. — Garon-Labrecque 13-070, 13-071 (MT). Scotty Creek, NWT, 61.297°N, 121.298°W. Shore of Goose Lake, with *Picea mariana*, *Schoenoplectus acutus*, and *Myrica gale*. Widespread North American.

DROSERACEAE

Drosera anglica Huds. — Fafard 39 (WLU), Garon-Labrecque 13-037 (MT). Scotty Creek, NWT, 61.299°N, 121.296°W. Rich fen with *Larix laricina*, *Arethusa bulbosa*, *Triglochin maritima*, *Pedicularis parviflora*, and *Platanthera aquilonis*. Circumpolar.

Drosera rotundifolia L. — Garon-Labrecque 13-011 (MT). Scotty Creek, NWT, 61.308°N, 121.304°W. Ubiquitous on the site. Circumpolar.

ELEAGNACEAE

Shepherdia canadensis (L.) Nutt. — Garon-Labrecque 13-138 (MT). Scotty Creek, NWT, 61.308°N, 121.292°W. Rich wooded areas dominated by *Picea mariana* and *Pleurozium schreberi*, with *Equisetum scirpoides*, *Larix laricina*, *Rhododendron groenlandicum*, and *Equisetum sylvaticum*. Widespread North American.

ERICACEAE

Andromeda polifolia L. — Garon-Labrecque 13-007 (MT). Scotty Creek, NWT, 61.308°N, 121.304°W. Bog with *Picea mariana*, *Chamaedaphne calyculata*, *Maianthemum trifolium*, *Drosera rotundifolia*, and *Carex* spp. Circumpolar.

Arctous rubra (Rehder & E. H. Wilson) Nakai — Garon-Labrecque 13-137 (MT). Scotty Creek, NWT, 61.309°N, 121.292°W. On peat plateau under the shade of *Picea mariana*, with *Equisetum scirpoides*, *Larix laricina*, *Rhododendron groenlandicum*, *Equisetum sylvaticum*, and *Pleurozium schreberi. East Asian—North American.*

Chamaedaphne calyculata (L.) Moench — Garon-Labrecque 13-062 (MT). Scotty Creek, NWT, 61.312°N, 121.306°W. Open bogs with other ericaceous species and *Eriophorum* spp. Circumpolar.

Empetrum nigrum subsp. *hermaphroditum* (Hagerup) Böcher — Garon-Labrecque 13-145 (MT). Scotty Creek, NWT, 61.306°N, 121.291°W. Peat plateau, under *Picea mariana*, with *Rubus chamaemorus*. Circumpolar.

Kalmia microphylla (Hook.) Ebinger var. *microphylla* — Garon-Labrecque 13-002 (MT). Scotty Creek, NWT, 61.308°N, 121.304°W. Bog with *Picea mariana*, *Andromeda polifolia*, *Chamaedaphne calyculata*, *Maianthemum trifolium*, *Drosera rotundifolia*, and *Carex* spp. Widespread North American.

Moneses uniflora (L.) A. Gray — Garon-Labrecque 13-058 (MT). Scotty Creek, NWT, 61.3099°N, 121.2931°W. Transition zone between fen and peat plateau, dominated by *Picea mariana*, *Larix laricina*, *Salix* spp., and *Sphagnum* spp. Circumpolar.

Orthilia secunda (L.) House — Garon-Labrecque 13-084 (MT). Scotty Creek, NWT, 61.309°N, 121.293°W. Peat plateau under tall *Picea mariana*. Circumpolar.

Pyrola asarifolia Michx. subsp. *asarifolia* — Garon-Labrecque 13-121 (MT). Scotty Creek, NWT, 61.310°N, 121.288°W. Peat plateau, in the shade of *Picea mariana* with *Galearis rotundifolia*. East Asian–North American.

Pyrola chlorantha Sw. — Garon-Labrecque 13-176 (MT). Scotty Creek, NWT, 61.298°N, 121.296°W. Near Goose Lake shore under the shade of *Picea* *mariana*, with *Equisetum scirpoides* and *Ribes hudsonianum*. Circumpolar.

Rhododendron groenlandicum (Oeder) Kron & Judd — Garon-Labrecque 13-128 (MT). SCOTTY CREEK, NWT, 61.301°N, 121.293°W. On peat plateaus, very common and abundant. Widespread North American.

Rhododendron tomentosum Harmaja — Garon-Labrecque 13-030 (MT). SCOTTY CREEK, NWT, 61.303°N, 121.299°W. Peat plateau, with *Picea mariana* and *Rhododendron groenlandicum*. East Asian–North American.

Vaccinium oxycoccos L. — Garon-Labrecque 13-003 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.305°W. Peat plateau dominated by *Rhododendron groenlandicum* and *Picea mariana*, with *Rubus chamaemorus*, *Vaccinium vitis-idaea*, and *Cladonia* spp. Circumpolar.

Vaccinium uliginosum L. — Garon-Labrecque 13-027 (MT). SCOTTY CREEK, NWT, 61.307°N, 121.302°W. Peat plateau dominated by *Picea mariana* and *Cladonia* spp. Circumpolar.

Vaccinium vitis-idaea L. — Garon-Labrecque 13-001 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.304°W. Bog with *Picea mariana*, *Andromeda polifolia*, *Chamaedaphne calyculata*, *Maianthemum trifolium*, *Drosera rotundifolia*, and *Carex* spp. Circumpolar.

GROSSULARIACEAE

Ribes cf. *glandulosum* Grauer — Garon-Labrecque 13-217 (MT). SCOTTY CREEK, NWT, 61.309°N, 121.292°W. On a peat plateau with *Picea mariana*, *Geocaulon lividum*, and *Rhododendron groenlandicum*. Widespread North American. A single young, immature specimen was collected. It lacks the abundant glandless white trichomes normally present on the abaxial leaf surfaces of *Ribes glandulosum* and might also be referable to a bristleless form of *Ribes lacustre*.

Ribes hudsonianum Richardson var. *hudsonianum* — Garon-Labrecque 13-146 (MT). SCOTTY CREEK, NWT, 61.307°N, 121.287°W. Peat plateau, half-shaded under *Picea mariana*. Widespread North American.

HALORAGACEAE

Myriophyllum verticillatum L. — Garon-Labrecque 13-050 (MT). SCOTTY CREEK, NWT, 61.307°N, 121.308°W. Shallow water near the shore of First Lake. Circumpolar.

HYDROCHARITACEAE

Najas flexilis (Willd.) Rostk. & W. L. E. Schmidt — Garon-Labrecque 13-016 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Shallow water near the shore of First Lake, anchored in thick layer of organic matter. Amphi-Atlantic.

LAMIACEAE

Lycopus uniflorus Michx. — Garon-Labrecque 13-040 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Shore of Goose Lake, in an *Equisetum fluviatile* stand. East Asian-North American.

Scutellaria galericulata var. *pubescens* Benth. Garon-Labrecque 13-013, 13-048 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Open marshy places near the shore of First Lake, often with *Carex rostrata*, *Calla palustris*, and *Menyanthes trifoliata*. Widespread North American.

LENTIBULARIACEAE

Pinguicula villosa L. — Garon-Labrecque 13-063 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Common on top of *Sphagnum* hummocks and peat plateaus under *Picea mariana*. Circumpolar.

Utricularia intermedia Hayne — Garon-Labrecque 13-014, 13-068, 13-163, 13-183 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Found in shallow water of lakes but also in open marshes under *Menyanthes trifoliata*. Circumpolar.

Utricularia minor L. — Garon-Labrecque 13-078 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Shallow water of lakes and wet bog depressions. Circumpolar.

Utricularia vulgaris L. — Garon-Labrecque 13-015, 13-017 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Floating in shallow water of lakes. Circumpolar.

MENYANTHACEAE

Menyanthes trifoliata L. — Garon-Labrecque 13-009 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.304°W. Ubiquitous in wet open habitats. Circumpolar.

MYRICACEAE

Myrica gale L. — Garon-Labrecque 13-127 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.292°W. Shore of Goose Lake with *Salix* spp. and *Alnus incana* subsp. *tenuifolia*. Circumpolar.

ONAGRACEAE

Chamerion angustifolium (L.) Holub subsp. *angustifolium* — Garon-Labrecque 13-110, 13-152 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Open dry areas near beaver huts. Circumpolar.

Epilobium leptophyllum Raf. — Garon-Labrecque 13-045, 13-173, 13-180 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Wet bogs and marshes. Widespread North American.

OROBANCHACEAE

Pedicularis labradorica Wirsing — Fafard 21 (WLU), Garon-Labrecque 13-123, 13-144 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.288°W. Rich peat plateaus dominated by *Picea mariana* and *Pleurozium schreberi*, with *Equisetum scirpoides*, *Larix laricina*, *Rhododendron groenlandicum*, and *Equisetum sylvaticum*. Circumpolar.

Pedicularis parviflora Smith — Garon-Labrecque 13-028, 13-208 (MT). SCOTTY CREEK, NWT, 61.301°N, 121.293°W. In fens and rich marshy bogs. Widespread North American.

POLYGONACEAE

Persicaria lapathifolia (L.) Delarbre — Garon-Labrecque 13-174 (MT). SCOTTY CREEK, NWT, 61.304°N, 121.294°W. In well-drained organic soil on the shore of Goose Lake, in full sun, with *Calamagrostis canadensis* var. *canadensis*, *Betula glandulosa*, and *Rumex britannica*. Circumpolar.

Rumex britannica L. — Garon-Labrecque 13-171 (MT). SCOTTY CREEK, NWT, 61.299°N, 121.296°W. Marsh on the shore of Goose Lake, dominated by *Equisetum fluviatile*, *Cicuta virosa*, and *Scutellaria galericulata* var. *pubescens*. Widespread North American.

PRIMULACEAE

Lysimachia thyrsiflora L. — Garon-Labrecque 13-052 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Fen with *Sphagnum* spp., *Comarum palustre*, *Carex aquatilis* var. *aquatilis*, *Carex magellanica* subsp. *irrigua*, and *Carex limosa*. Circumpolar.

RANUNCULACEAE

Coptidium lapponicum (L.) Gand. ex Rydb. — Garon-Labrecque 13-213 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.290°W. Wet mossy depression under the shade of a tall *Picea mariana* stand, with *Larix laricina*, *Rhododendron groenlandicum*, *Vaccinium uliginosum*, and *Chamaedaphne calyculata*. Circumpolar.

ROSACEAE

Comarum palustre L. — Garon-Labrecque 13-055 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Common in marshes with *Carex aquatilis* var. *aquatilis*, *Carex rostrata*, and *Calla palustris*. Circumpolar.

Dasiphora fruticosa (L.) Rydb. — Garon-Labrecque 13-112 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.288°W. Opening in a forested peat plateau with *Picea mariana*, *Larix laricina*, *Vaccinium uliginosum*, and *Sphagnum* spp. Circumpolar.

Potentilla norvegica L. — Garon-Labrecque 13-150 (MT). SCOTTY CREEK, NWT, 61.302°N, 121.305°W. Growing on top of a beaver lodge with *Chamerion angustifolium* subsp. *angustifolium* and *Urtica dioica* subsp. *gracilis* on First Lake shore. Circumpolar.

Rosa acicularis Lindl. — Garon-Labrecque 13-207 (MT). SCOTTY CREEK, NWT, 61.298°N, 121.299°W. Semi-open area in *Picea mariana* and *Pinus banksiana* stand, with *Juniperus communis* var. *depressa* and *Cornus canadensis*. Circumpolar.

Rubus arcticus subsp. *acaulis* (Michx.) Focke — Garon-Labrecque 13-090, 13-109 (MT). SCOTTY CREEK, NWT, 61.310°N, 121.290°W. Peat plateaus with *Picea mariana*, *Vaccinium vitis-idaea*, *Vaccinium oxycoccos*, and *Sphagnum* spp. Widespread North American.

Rubus chamaemorus L. — Garon-Labrecque 13-004, 13-211 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.305°W. Very common on peat plateaus and in bogs. Circumpolar.

RUBIACEAE

Galium labradoricum (Wiegand) Wiegand — Garon-Labrecque 13-054 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Marsh, straggling on *Comarum palustre* and *Menyanthes trifoliata*. Widespread North American.

Galium trifidum L. — Garon-Labrecque 13-047 (MT). SCOTTY CREEK, NWT, 61.298°N, 121.299°W. Open fen dominated by *Carex rostrata* and *Menyanthes trifoliata*. Circumpolar.

SALICACEAE

Populus balsamifera L. — Garon-Labrecque 13-225 (MT). SCOTTY CREEK, NWT, 61.306°N, 121.295°W. Open area at the transition between a peat plateau and a fen. Widespread North American.

Populus tremuloides Michx. — Garon-Labrecque 13-167, 13-205 (MT). SCOTTY CREEK, NWT, 61.297°N, 121.303°W. Peat plateaus and sandy hills. Widespread North American.

Salix arbusculoides Andersson — Garon-Labrecque 13-169 (MT). SCOTTY CREEK, NWT, 61.300°N, 121.304°W. Open dry area with *Salix* spp., *Populus balsamifera*, and *P. tremuloides*. West American.

Salix bebbiana Sarg. — Garon-Labrecque 13-206, 13-219 (MT). SCOTTY CREEK, NWT, 61.311°N, 121.286°W. On peat plateaus, opening in a *Picea mariana* stand, with *Larix laricina, Rhododendron groenlandicum*, and *Chamaedaphne calyculata*. Widespread North American.

Salix discolor Muhl. — Garon-Labrecque 13-218 (MT). SCOTTY CREEK, NWT, 61.298°N, 121.297°W. Sandy hill near Goose Lake shore, opening in a *Picea mariana* stand, with *Salix* spp., *Vaccinium uliginosum*, and *Myrica gale*. Widespread North American.

Salix glauca var. *acutifolia* (Hook.) C. K. Schneid.— Garon-Labrecque 13-166 (MT). SCOTTY CREEK, NWT, 61.300°N, 121.304°W. Open transitional area between bog and peat plateau, with *Betula glandulosa* and *Populus tremuloides*. Widespread North American.

Salix lasiandra Benth. — Garon-Labrecque 13-190 (MT). SCOTTY CREEK, NWT, 61.312°N, 121.292°W. Open wet area with *Larix laricina*, *Picea mariana*, *Betula glandulosa*, *Chamaedaphne calyculata,* and *Equisetum*. West American.

Salix myrtillifolia Andersson — Garon-Labrecque 13-147, 13-196, 13-215 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.298°W. Rich wet semi-open areas in *Picea mariana* stands on peat plateaus, with *Rhododendron groenlandicum* and other shrubs. Widespread North American.

Salix pedicellaris Pursh — Garon-Labrecque 13-100, 13-101, 13-149 (MT). SCOTTY CREEK, NWT, 61.300°N, 121.304°W. Very common in wet and open areas with *Carex* spp. Widespread North American.

SANTALACEAE

Geocaulon lividum (Richardson) Fernald — Garon-Labrecque 13-031 (MT). SCOTTY CREEK, NWT, 61.303°N, 121.299°W. Peat plateaus with many species of *Cladonia* spp., *Picea mariana*, and *Rhododendron groenlandicum*. Widespread North American.

SARRACENIACEAE

Sarracenia purpurea L. — Garon-Labrecque 13-074 (MT). SCOTTY CREEK, NWT, 61.300°N, 121.302°W. Common in fens and rich bogs. Widespread North American.

SAXIFRAGACEAE

Mitella nuda L. — Garon-Labrecque 13-111, 13-191 (MT). SCOTTY CREEK, NWT, 61.312°N, 121.292°W. Rich shady peat plateaus. East Asian–North American.

SCHEUCHZERIACEAE

Scheuchzeria palustris L. — Garon-Labrecque 13-008 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.304°W. Bog with *Picea mariana*, *Andromeda polifolia*, *Chamaedaphne calyculata*, *Maianthemum trifolium*, *Drosera rotundifolia*, and *Carex* spp. Circumpolar.

TYPHACEAE

Sparganium angustifolium Michx. — Garon-Labrecque 13-059 (MT). SCOTTY CREEK, NWT, 61.293°N, 121.293°W. Shallow, dark water of Goose Lake, anchored in deep organic layer, pH near neutral. Circumpolar.

Sparganium natans L. — Garon-Labrecque 13-056, 13-182 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Marshes with *Myrica gale*, *Typha latifolia*, *Calla palustris*, *Menyanthes trifoliata*, and *Carex aquatilis* var. *aquatilis*. Circumpolar.

Typha latifolia L. — Garon-Labrecque 13-060 (MT). SCOTTY CREEK, NWT, 61.293°N, 121.307°W. Common in swamps and along the shores of lakes, often with *Myrica gale*. Circumpolar.

URTICACEAE

Urtica dioica subsp. *gracilis* (Aiton) Selander — Garon-Labrecque 13-139, 13-151 (MT). SCOTTY CREEK, NWT, 61.308°N, 121.307°W. Open area on a beaver lodge with *Chamerion angustifolium* subsp. *angustifolium*. Widespread North American.

Acknowledgements

Special thanks to Vincent Hamman-Benoit who helped to collect and dry the plants and Cory Wallace who swam among the leeches to get some aquatic plants. We are grateful to Suzanne Carrière and Bonnie Fournier (Environment and Natural Resources, Government of the Northwest Territories) for giving us access to critical information on NWT plant specimens. Nicolas Pelletier gave us access to a soil core for chemical tests. Sarah Vinge-Mazer and Denver Falconer (SASK) helped to locate the closest *Arethusa bulbosa* locality. Thanks also go to George Argus (CAN) who confirmed our *Salix* identifications. Nos remerciements à Jacques Cayouette (DAO) pour son avis sur les Cypéracées. Melissa Fafard shared some of her interesting plant collections from Scotty Creek. Jacques Cayouette and Bruce Bennett provided useful comments on a previous version of the manuscript. Collection of plant specimens was authorized by Aurora Research Institute Licence number 15200. This research was led by Marie-Ève Garon-Labrecque as part of an undergraduate research internship at the Université de Montréal with support from a Canadian Polar Commission Northern Scientific Training Program grant. Additional support was provided by a Natural Sciences and Engineering Research Council Discovery Grant awarded to Oliver Sonnentag.

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Received 14 November 2014
Accepted 29 July 2015

White-tailed Deer (*Odocoileus virginianus*) Fawn Risk from Gray Wolf (*Canis lupus*) Predation During Summer

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Mech, L. David, Aaron Morris, and Shannon Barber-Meyer. 2015. White-tailed Deer (*Odocoileus virginianus*) fawn risk from Gray Wolf (*Canis lupus*) predation during summer. Canadian Field-Naturalist 129(4): 368–373.

Little is known about how often various prey animals are at risk of predation by Gray Wolves (*Canis lupus*). We used a system to monitor the presence during the day of two radio-collared Gray Wolves within 2 km of a radio-collared White-tailed Deer (*Odocoileus virginianus*) with a fawn or fawns in August 2013 in the Superior National Forest of northeastern Minnesota. We concluded that the fawn or fawns were at risk of predation by at least one wolf at least daily.

Key Words: Gray Wolf; *Canis lupus*; White-tailed Deer; *Odocoileus virginianus*; fawn; predation; hunting behaviour; radio-tracking; Superior National Forest; Minnesota

Introduction

Almost nothing is known about how often any individual prey animal is at risk of contending with predators, yet "predation risk is key to understand prey population dynamics" (Pettorelli *et al.* 2011: 307). No doubt the frequency at which any individual prey is "tested" (Mech 1966) by predators is highly variable depending on predator and prey species, the density of each, and many other factors. Nevertheless, any information on this subject would be revealing and would improve our understanding about how some prey survive for years in the face of wolf predation while others are killed (Mech *et al.* 2015).

Information currently available about how often individual prey get tested by wolves consist of a few scattered reports with various types of data. For White-tailed Deer (*Odocoileus virginianus*) fawns in the Superior National Forest of Minnesota during summer, preliminary evidence indicates that a given doe and fawn could be visited by a Gray Wolf (*Canis lupus*) every 3–5 days (Demma *et al.* 2007) or, according to another study, wolves visit specific doe–fawn groups in their territory an average of about once every 13–20 days (Demma and Mech 2009a). In Yellowstone National Park, wolves came within 1 km of Elk (*Cervus elaphus*) an average of every 9 days, which the authors considered a reasonable proxy for how often Elk were at risk from the wolves (Middleton *et al.* 2013). Based on 1265 concurrent fixes of a Moose (*Alces alces*) and a wolf (five Moose in the territory of two wolves, all wearing a Global Positioning System [GPS] radio collar), only 0.11% of all Moose fixes were within 1 km of a wolf (Eriksen *et al.* 2009).

In our study area, the main prey of wolves during summer is White-tailed Deer fawns (Frenzel 1974; Van Ballenberghe *et al.* 1975; Nelson and Mech 1986; Kunkel and Mech 1994). During the month of our study, fawns usually spend much of their time with their mother or within 100 m of her on average (Ozoga *et al.* 1982). To gain further insight into how often individual fawns might be at risk from wolves in our area, we used a data-logging, radio-receiver system to detect how often either of two radio-collared wolves came reasonably close to fawns accompanying a radio-collared doe in the wolves' territory. We assume that wolves coming close to fawns represent a reasonable measure of wolves hunting fawns as per Eriksen *et al.* (2009) and Middleton *et al.* (2013).

Study Area

We conducted the study in the Superior National Forest, approximately 22 km southeast of Ely, Minnesota (48°N, 92°W) within the much larger area of a long-term wolf and deer investigation (Mech 2009). The area is generally flat and forested, with scattered open lowlands and a few logging roads. Summer temperatures generally range from 20°C to 35°C. During the previous winter, wolf density in the territory encompassing our study area was 38.5/1000 km^2 (see Methods), and an estimate of deer density was 0.4-2.7 adult deer/km^2 (Lenarz and Grund 2011). The wolf pack that includes the two radio-collared wolves apparently included a litter of pups during the study because the pack increased from three members in winter 2012–2013 to six in 2013–2014 (LDM and SBM, unpublished observations). For more details about the study area, see Mech (2009).

Methods

Two female wolves (numbered 7117 and 7205) estimated to be 5 and 3 years old (Gipson *et al.* 2000) from the same pack and collared with very-high-frequency (VHF) radios for other research (Mech 2009) were the subjects of this study, along with VHF radio-collared doe 8330, aged 8 years by incisor sectioning (Gilbert 1966). The composite territory (100% minimum-convex polygon) of the wolves included the home range of doe 8330 (Figure 1). From 2 April to 22 October 2013, the territory of the wolves included 78 km^2 (based on 31 locations detected from the air), and the home range of the doe, toward the northern edge of the wolf territory, occupied approximately 0.93 km^2 (based on nine locations detected from 30 May to 4 June 2012 and six from 8 June to 3 July 2013), some 1.2% of the area of the wolves' territory. The wolf collars transmitted between 0800 and 2000, and the deer collar between 0940 and 2135.

A stationary radio-tracking system (R4500S receiver/data logger; Advanced Telemetry Systems, North Isanti, Minnesota, USA) with an omnidirectional antenna recorded the presence of radio-collared wolves and deer within a 1.0-km radius of the detection site from 29 July through 29 August 2013 (although on only part of the first and last days). The system was deployed so that its programmed detection area covered the entire estimated summer range of the doe (Figure 1). About half the home range of another radio-collared doe also fell within the detection area, and other non-collared deer could also have lived in the detection area along with their fawns. Our objective was to detect the radio-collared wolves only while they were within the detection area while their transmitters were active.

The receiving and data-logging units were protected in a hardened plastic box; cables were threaded through a hole in the side rim of the plastic lid of the box and sealed with silicon. The omnidirectional antenna was mounted on a wooden platform about 2 m off the ground against a tree. The entire unit was powered by a heavy-duty marine battery, also housed inside the box. The box was padlocked shut and cable-locked to a tree, and a warning/information label was affixed to the top of the box. We programmed the frequencies of the wolves and deer into the receiver and set the search function to check them every 5 minutes.

To calibrate the detection radius of the receiver and data logger, we carried a test collar of the same type used on both the wolves and the deer, at wolf height to simulate deployed collars, to different areas along concentric circles at various distances from the system to the edges of the desired detection area (3.14 km^2), a radius of 1.0 km. We manually recorded test times and locations and compared them with the system-recorded times. We adjusted the receiver gain and repeated the tests until the system approximately monitored the desired study area but not beyond the 1.0-km radius.

The radio-collared doe whose range was within the radio-tracking system was included in the monitoring sequence to test the system's reliability. If the system's detection range was constantly covering the prescribed range, the system should always detect the deer while its transmitter was active.

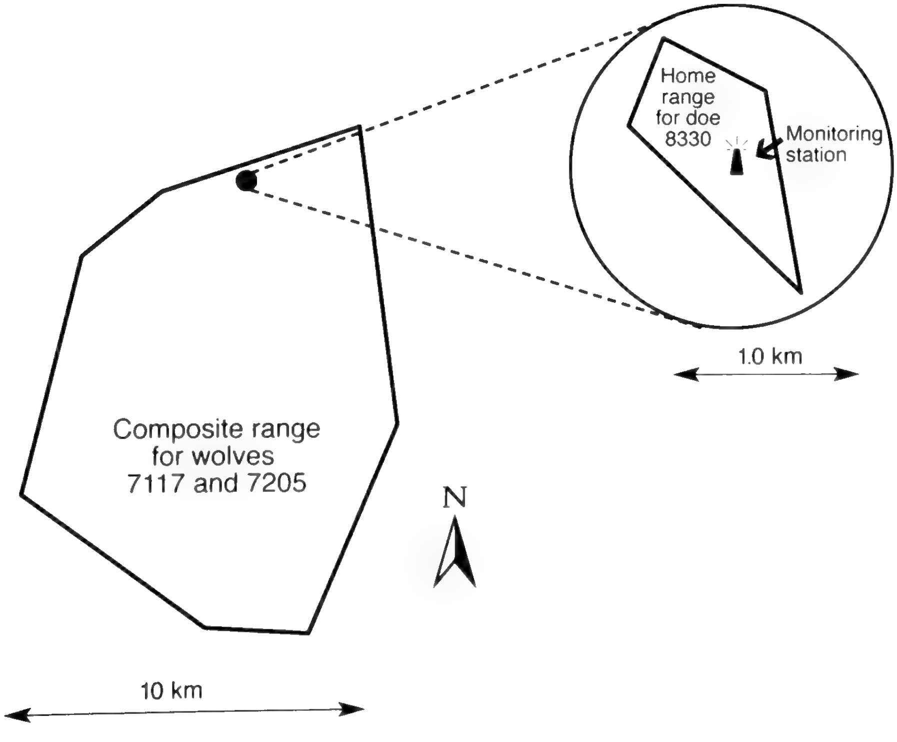

FIGURE 1. Diagram of the monitoring system for detecting radio-collared Gray Wolves (*Canis lupus*) and White-tailed Deer (*Odocoileus virginianus*) in the Superior National Forest study area, Minnesota, 29 July to 29 August 2013.

We downloaded the stored data about once a week, and exchanged the battery for a freshly charged one at the same time.

Because our objective was to determine how often our radio-collared wolves approached the vicinity of fawns, we searched weekly for fawn tracks within the home range of our collared doe in selected areas of adequate tracking substrate.

Results and Discussion

We found fawn tracks during five of the six surveys from 29 July through 26 August 2013. Although we found no tracks on 29 August, that survey was preceded by a heavy rainstorm that would have washed out any tracks. Thus at least one fawn, and probably more because mature does often produce twins (Verme and Ullrey 1984; DelGiudice *et al.* 2007) and because at least two does occupied a portion of the detection range, were present in the study area throughout most or all of the study.

The monitoring system detected the radio-collared doe every day, an average of 81% of the time during each day. We have no way of knowing whether lack of detection meant the deer was out of range or in a position where the system could not detect her. If she was outside the detection range, it probably was not for long because she was detected every day, at least 40% of the time (except for the partial first day). If lack of detection was because she was in a poor position (e.g., shielded from the antenna by the tree the antenna was mounted against) and, if the same problem pertained to wolf detection, that would make our conclusions about how often the fawns were at risk of wolf predation less than actual.

The monitoring system detected wolf 7117 on 24 of the 32 12-h days (Figure 2) and wolf 7205 on 22 days (Figure 3). However, on several days, only one-to-a-few detections were made. To better relate wolf detections to possible interactions with fawns, we arbitrarily chose to omit all the four or fewer consecutive detections (representing 20 minutes). We chose that value because at an assumed travel rate of 6.0 km/h, a wolf could cross the widest expanse of a 1.0-km-radius reception circle in that time. Wolves travel at about 8 km/h while crossing frozen waterways and open tundra (Mech 1994), but we assumed that wolves would travel more slowly through the forested underbrush of our study area, especially when searching for prey. Given these assumptions, wolf 7117 recorded four or more consecutive detections on 6 days (Figure 2). Wolf 7205 met that criterion on 11 days (Figure 3). Because the wolf transmitters were active only half the time (12 h/day)

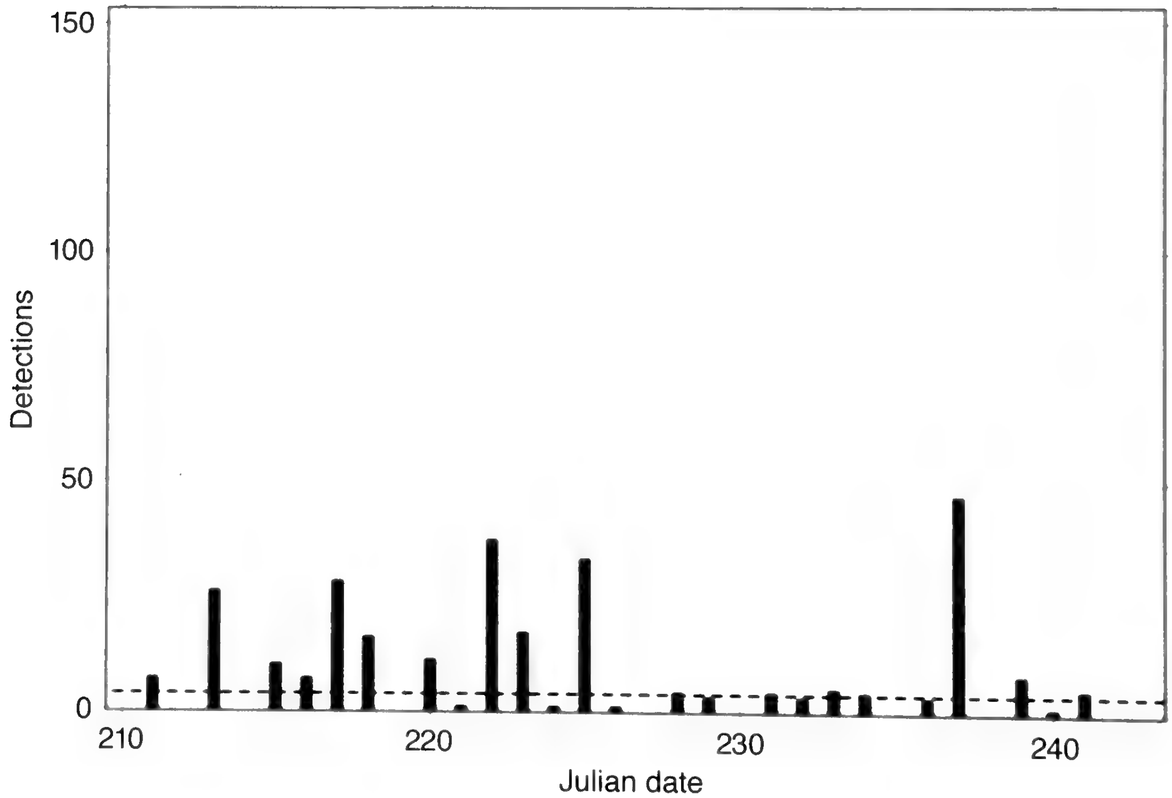

FIGURE 2. Temporal distribution of the presence of Gray Wolf (*Canis lupus*) 7117 within 1 km of the monitoring station in the Superior National Forest study area, Minnesota, 29 July to 29 August 2013 (Julian dates 210–241). Number of detections possible per day = 144. Dashed line indicates 4 consecutive detections.

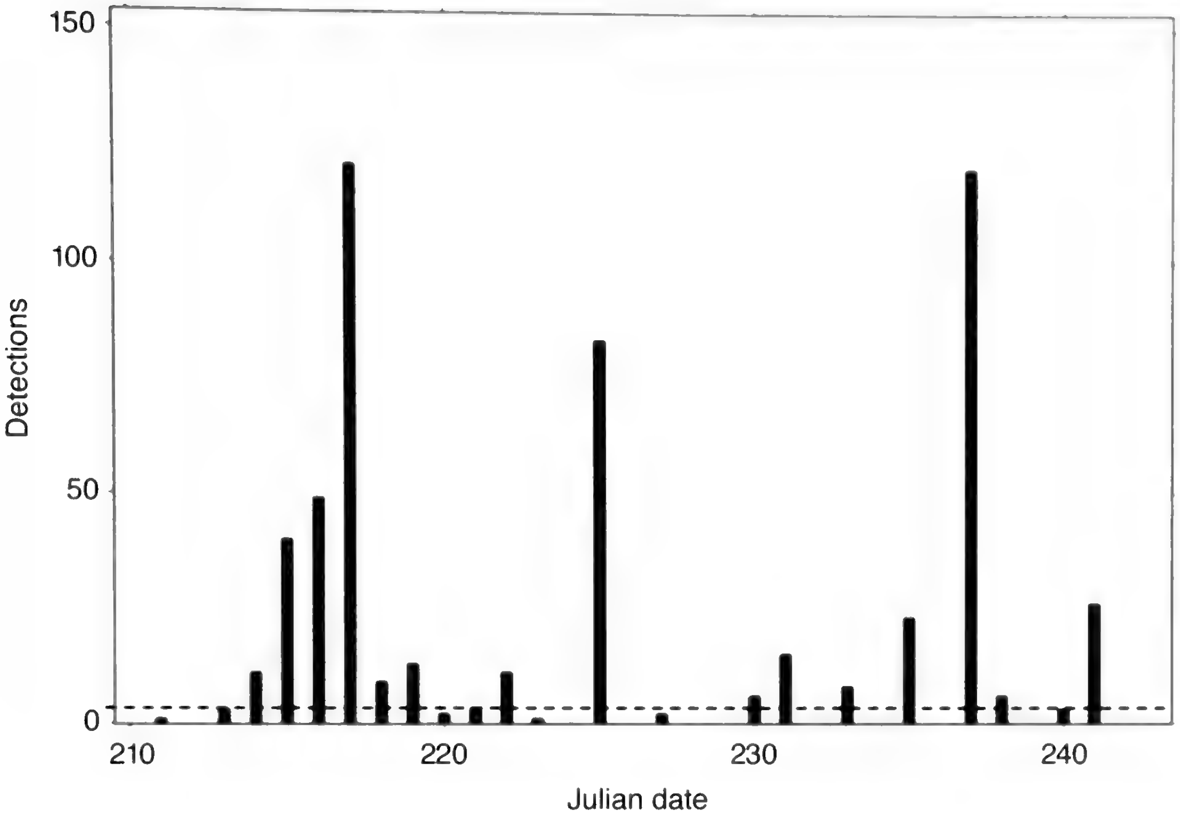

FIGURE 3. Temporal distribution of the presence of Gray Wolf (*Canis lupus*) 7205 within 1 km of the monitoring station in the Superior National Forest study area, Minnesota, 29 July to 29 August 2013 (Julian dates 210–241). Number of detections possible per day = 144. Dashed line indicates 4 consecutive detections.

and because wolves are generally more active at night than during the day, these figures should be considered minimal. The two wolves were separate all four times they were found by aerial tracking during the study and all five times they were found before the study, so their proximities to fawns should be considered additive (see below).

Using the conservative criterion of four or more consecutive detections, and accounting for 3 days when both wolves were detected, at least one radio-collared wolf spent at least 20 minutes within 2 km of the fawn or fawns of the radio-collared doe during the day on at least 14 of the 32 days of the study.

In addition, we observed wolf 7117 with two other wolves during the preceding winter, one of which could have been wolf 7205. During summer in this region, members of wolf packs tend to hunt separately (Demma *et al.* 2007; Demma and Mech 2009b; Palacios and Mech 2010; Barber-Meyer and Mech 2015). Therefore, there is a strong probability that the fawn or fawns in our study were approached by non-radio-collared wolves as well as by our tracked wolves and, thus, more often than our findings indicate.

The wolves spent more time in the relatively small monitored area (4% of the wolves' territory) than the full area of their territory: wolf 7117 spent 6% of its time (556 of 4608 possible detections) there and wolf 7205 spent 12% (282 detections). On 25 August, wolf 7205 spent 10 h in the monitored area (Figure 3). These findings are in accord with the assumption that the wolves were hunting the fawns. Although we cannot directly relate wolf detections by the monitoring system to attempts by the wolves to search for and attempt to capture fawns, it is reasonable to assume that most of the wolves' time spent within the monitoring area was related to such attempts. Because the home range of the radio-collared doe comprised such a high percentage of the detection area, even if the wolves used the space within the detection area randomly, they would be within that home range a high percentage of the time. In addition, fawns form the main prey of wolves during summer in this area as indicated above, so wolves must spend much of their time trying to capture fawns. Because of the amount of time the wolves spent in the monitored area, they were likely aware of the fawns' presence. Even if the wolves entered from the opposite side of the monitored area from the fawns' location, they would likely have been able to smell them or at least know where to travel to search for them and would have been able to reach them within a few minutes.

Similar to Middleton *et al.* (2013) and Eriksen *et al.* (2009), we assumed that wolves anywhere within the monitoring distance of our system were probably a threat to fawns, although in extreme cases, a detected wolf could have been as far as 2 km from a fawn.

Nothing is known about how difficult and time-consuming it is for a wolf to find, catch, and kill fawns the age of those during our monitoring, but some information suggests that, in the same general area as ours, wolves spend 20–22 h and travel 1.5–3.0 km around the site of a killed fawn (Demma *et al.* 2007). It would not take much time to consume a fawn; thus, presumably much of this time and travel is spent searching for, chasing, and trying to catch and kill it.

Our findings support those of Demma *et al.* (2007) and Demma and Mech (2009a) that wolves in the Mech (2009) study area spend considerable time near deer fawns and that most fawns are apparently tested by wolves frequently. Our findings suggest that fawns in our study area are probably tested daily by at least one wolf. However, earlier studies in the same region have concluded that in the territory of a pack of five wolves, 1 year old or older, hunting individually, some would visit each doe/fawn about every 3–5 days on average (Demma *et al.* 2007) or about once every 13–20 days (Demma and Mech 2009a). Any number of explanations are possible for the differences between the earlier studies and ours, including the following: (1) our study detected wolves only during the day, whereas the other studies were based on collars recording locations day and night; (2) the ranges of the deer in the earlier studies were generally about a third larger than those in our study; and, probably most important, (3) the wolf pack territory in the earlier studies was about four times the size of the wolf territory in our study and the wolf density about 60% of that of our study (SBM and LDM, unpublished observations).

In the region in and around our study area, 49% of fawns survived from May through October during two earlier summers, with wolves causing half the deaths (Kunkel and Mech 1994). Considering all of the above, it appears that, even though deer fawns are small, inhabit local areas where they can easily be found, and do not possess the strength, power, or other defensive characteristics of adult deer (Mech *et al.* 2015), their ability to survive in the face of frequent attempts by wolves to hunt them is remarkable, at least in our study area, even though they are well defended by their doe (Mech 1984).

Although our findings regarding deer fawn risk of predation by wolves are indirect and imprecise, they help strengthen earlier findings and add more information to the little-studied question of individual prey risk and, thus, to the larger subject of prey population dynamics (Pettorelli *et al.* 2011) from the perspective of the prey.

Additional research on this subject is warranted based on new questions that arose during this study. Does the rate of wolf visits to a doe's home range increase on parturition? Does it decline following fawn mortality? Does it vary across seasons, irrespective of fawn presence?

For subsequent investigations about these and related questions, we recommend several improvements in study design. To better document wolf presence, we suggest: (1) mounting the antenna freestanding rather than attaching it to a tree, (2) using 24-h radio-collars on wolves, and (3) using GPS collars to provide a finer level of wolf data (Demma *et al.* 2007). We suggest supplementing track surveys with the use of trail cameras to better detect fawn presence and minimum abundance. We also suggest expanding the duration of future studies to include the first 5 months of the life of fawns, the entire period when wolves in this area concentrate on hunting fawns (Nelson and Mech 1986), and extending them throughout the fall when fawns transition to near adult size and become more difficult to kill. Radio-collaring more deer in the study area is also recommended.

Acknowledgements

This study was funded by the United States Geological Survey. We thank D. A. Brandt for lending us the monitoring equipment, several volunteer technicians, and G. D. DelGiudice, who reviewed the article. Any mention of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the United States government.

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Received 22 April 2015
Accepted 7 October 2015

Response of Wild Trumpeter Swan (*Cygnus buccinator*) Broods to Wetland Drawdown and Changes in Food Abundance

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Lumsden, Harry G., Vernon G. Thomas, and Beren W. Robinson. 2015. Response of wild Trumpeter Swan (*Cygnus buccinator*) broods to wetland drawdown and changes in food abundance. Canadian Field-Naturalist 129(4): 374–378.

A brief period of drawdown can stimulate wetland productivity and enhance the attractiveness of a site for breeding Trumpeter Swans (*Cygnus buccinator*) by providing a nutrient pulse. Drawdown of a pond in Aurora, Ontario, lasting about 8 weeks in late summer and fall 2009 followed by re-flooding increased the abundance of invertebrates, especially snails, in the following year. This response was ephemeral, lasting 1 year. Wild Trumpeter Swans and their cygnets responded by selective feeding the year after drawdown, despite the risk of predation by Snapping Turtles (*Chelydra serpentina*). There was a strong correlation between the feeding activity of two cygnets and the local abundance of snails in the pond in 2010. The nutritional content, especially protein, calcium, phosphorus, and magnesium, of a variety of abundant foods satisfied the requirements for skeletal growth and development and was higher than that of available commercial duck grower rations. The responsive feeding behaviours of the cygnets are typical of specific appetitive behaviour and suggest that swans rapidly exploit unpredictable nutrient fluxes in their local environment.

Key Words: Trumpeter Swan; *Cygnus buccinator*; cygnets; appetite; feeding behaviour; grass; snails; nutrients; drawdown

Introduction

The current continental range of the Trumpeter Swan (*Cygnus buccinator*) extends across habitats that are disturbed naturally by fire, drought, and flooding (Sibley 2000). These disturbances may disrupt the activities of swans in the short term, but they may also generate food pulses (Yang *et al.* 2008, 2010). The wide-scale significance of drought to waterbirds is well known (Murkin *et al.* 1982; Frederick and Ogden 2001), yet anthropogenic disturbances that mimic natural ones are less well understood. How such disturbances affect species composition of wetlands and the subsequent feeding behaviour of individual Trumpeter Swans has not been studied. We report on the selective feeding of cygnets the year following drawdown in a managed pond in 2009 and the availability and nutritional quality of their foods.

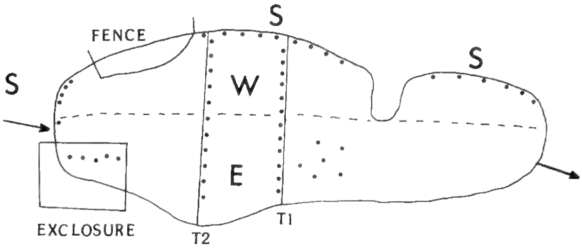

FIGURE 1. Diagram of the managed pond at Aurora, Ontario, used by breeding wild Trumpeter Swans (*Cygnus buccinator*). The direction of water flow through the pond is shown by arrows. Sampling transects (T1 and T2) across the pond were used to estimate invertebrate abundance from 2010 to 2013. Dots represent sampling sites in 2010. West, East, and Shore sectors are denoted by W, E, and S.

Study Area

A managed pond that can be drawn down and reflooded in Aurora, Ontario (44°00'N, 79°28'W) provided an opportunity to study how Trumpeter Swan behaviour responds to the effects of drawdown. Wild Trumpeter Swans have flown into this pond and raised broods from 2006 to 2014. The 0.4-ha pond is 60 cm deep; it is fed by a pipe from a creek at its southeast corner and drains through a pipe at its north end (Figure 1). In 2010, a small exclosure pen (water surface area 102 m^2) in the southeast corner of the pond supported clumps of rushes (*Juncus canadensis*), and a small exclosure (water surface area 76 m^2) on the west side protected a stand of Pickerelweed (*Pontederia cordata* L.). Elsewhere in the pond, swan grazing has eliminated all macrophytes. On the east side of the pond lies a mowed lawn on which wild Trumpeter Swan broods frequently graze.

The pond was drawn down to dryness in August 2009, 10 years after a previous drawdown. It was reflooded on 2 October the same year. It was drawn down and refilled again between 20 July and 30 September 2011.

Methods

To measure invertebrate abundance in three sectors of the pond (Figure 1), 10–12 mud samples were collected at marked 2-m intervals along two transects running east–west across the pond. Bottom samples were also collected within 0.5 m of the shore ($n = 19$ in 2010).

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalist's Club.

The eastern shore was not sampled because the cygnets did not forage in the gravel substrate. Benthic invertebrates were sampled from the pond in the summer, 2010–2013, and in fall 2013 with a circular bucket (area 537.3 cm^2) from which the bottom had been removed. It was forced through the mud into the substrate to collect bottom samples. From 2.5 to 3.5 L of mud were collected for each sample, although near shore sometimes as little as 1 L was available. Sediments were washed through a 1.2-mm mesh screen, and invertebrates were counted and preserved. Live and dead snails were identified by the presence or absence of soft tissue. Invertebrate samples were identified by Dr. G. Mackie (Department of Integrative Biology, University of Guelph). Grass samples were collected from the lawn by mowing and raking. The protein, calcium, phosphorus, and magnesium content of both snails and grasses were analyzed routinely by Laboratory Services at the University of Guelph.

Activity budgets for cygnet feeding behaviour were recorded for 15 s every consecutive 2 minutes on land totalling 31.7 h between 4 and 12 July 2010, and on water by sector totalling 11.4 h between 11 and 29 August 2010. The brood moved freely from sector to sector. The East sector was 51.6% surface area, the West sector was 45.9% of the area, and a 0.5 m wide Shore sector covered 2.6% of the surface area. We calculated sector preference of each cygnet (distinguishable by plumage colour) from their daily scores for the East, West, and Shore sectors following Johnson (1980), and ranked the daily use of the three sectors for each cygnet over 17 observation days. Daily sector preferences for each cygnet were estimated as the difference between daily rank sector use scores and rank sector availability (assumed to remain constant) and then averaged over 17 days. A sector preference score of zero indicates that the sector was used in proportion to its available surface area. Negative scores indicate a greater relative preference than expected from its availability, and positive scores indicate greater avoidance.

To determine whether benthic snail density varied spatially, we divided samples into three sector categories and the exclosure area, where swans were unable to feed. We divided each transect at its centre into an eastern half (4–15 m from eastern shoreline) and western half (16–26 m from eastern shoreline). The Shore sector was along the shore on the west (n = 9), northwest (n = 6), and south (n = 4) sides of the pond. We first used an analysis of variance (ANOVA) to test for differences in mean snail counts between northwest, south, and west shore samples. We then tested for differences between the combined east transect halves, combined west transect halves, Shore (combining shore samples), and the western Exclosure. Post-hoc comparisons were then made among these categories using Tukey's honest significant difference test ($a = 0.05$). Snail counts were Poisson distributed and, thus, were transformed into their natural log to homogenize variance. Relative pond-sector preference by cygnets could not be statistically tested because the number of individuals observed was less than the number of sectors (Johnson 1980) and because cygnet activity showed considerable coordination causing pseudo-replication.

Results

Food abundance and swan response in 2010

In 2010, a brood of four cygnets hatched on a raft on 12 June; two subsequently disappeared. On 14 June, the remaining cygnets began to feed on duck grower pellets, but after 23 June did not accept them. Instead, they tipped and grubbed in the pond and grazed on the lawn.

Benthic sampling of invertebrates in late June showed abundant snails (Table 1), the majority of which were *Physella gyrina* (94%). Six other species of snails were present as well as clams (*Pisidium adamsi* and *Sphaerium simile*), and leeches (*Erpobdella punctata* and *Helobdella triserialis*). Samples also contained a few oligochaetes as well as a mix of other invertebrates, such as Anisoptera nymphs, Coleoptera and Chironomid larvae, and *Notonecta* spp. Although the cygnets probably ate some of these invertebrates, their combined biomass was much smaller than that of the snails. The pond supported abundant Fathead Minnows (*Pimephales promelus*), which were restored after drawdown. A few Creek Chub (*Semotilus atromaculatus*) were present in 2011. Snapping Turtles (*Chelydra serpentina*) and Painted Turtles (*Chrysemys picta*) were present throughout the study period. Activity budgets recorded over 31.7 h during 4–12 July showed that the cygnets were feeding during 36–52% of daylight hours (Figure 2). Water feeding was confined largely to late morning when the time devoted to it exceeded that of grazing on land.

This study had not been anticipated in 2009 when anecdotal evidence suggested snail scarcity. In 2010, snails were not distributed randomly among the three sectors of the pond. There was no significant difference in the mean number of snails between the south and west parts of the Shore ($F_{2,16} = 2.1$, $P = 0.16$ [not significant]), and so these were combined to estimate Shore snail abundance. The mean number of snails differed significantly among the three sectors and the Exclosure ($F_{3,43} = 64.4$, $P < 0.0001$, adjusted $R^2 = 0.81$). Multiple comparisons revealed that live snail density in the Shore sector (1434/m^2) was significantly higher than in the East (349/m^2) and the West sectors (100/m^2) (Table 1). Snail density was 3.5 times higher in the East sector than in the West sector and 1.8 times greater in the Exclosure (618/m^2) than in the adjacent East sector.

Activity budgets recorded during 11.4 h of grubbing time over 11–29 August indicated that the cygnets strongly preferred the Shore sector (relative sector preference −1.43), even though it was the least available sector in the pond based on its surface area (relative sector preferences: West 0.60 and East 0.82) (Figure 3). Mean cygnet preference for pond foraging sector was

TABLE 1. The abundance of snails in bottom mud in a pond in Aurora, Ontario, 2010–2013.

Year and sector	Sample size	Dates sampled	Number of snails Live	Mean ± SD*	Dead	Mean ± SD	Live/m^2
2010							
East	13	27 30 July	225	18.7 ± 9.8a	111	9.2 ± 4.9	349
West	11	1–2 August	59	5.4 ± 2.7b	29	2.6 ± 1.3	100
Shore	19	13 August–9 September	1464	77.1 ± 21.6c	721	37.9 ± 10.6	1434
Exclosure	5	4–6 July	166	33.2 ± 11.5a	82	16.4 ± 6.0	618
2011							
East	12	27–30 July	3		83	6.9 ± 2.8	
West	10	2–3 August	2		42	4.2 ± 3.4	
Shore	12	16–24 August	10	0.8 ± 1.3	564	47.0 ± 20.2	15
2012							
East	10	28 July	1		23	2.3 ± 1.7	
West	10	29 July	1		9	0.9 ± 1.0	
Shore	10	30 July–1 August	2		172	17.2 ± 7.0	
2013							
East	11	26 July	0		16	1.5 ± 0.8	
West	11	28 July	0		5	0.5 ± 1.4	
Shore	10	29–31 July	1		201	20.1 ± 10.2	
Shore	10	17–22 October	61	6.1 ± 4.4	217	21.7 ± 19.9	

Note: SD = standard deviation.
*Values followed by different letters are significantly different from each other.

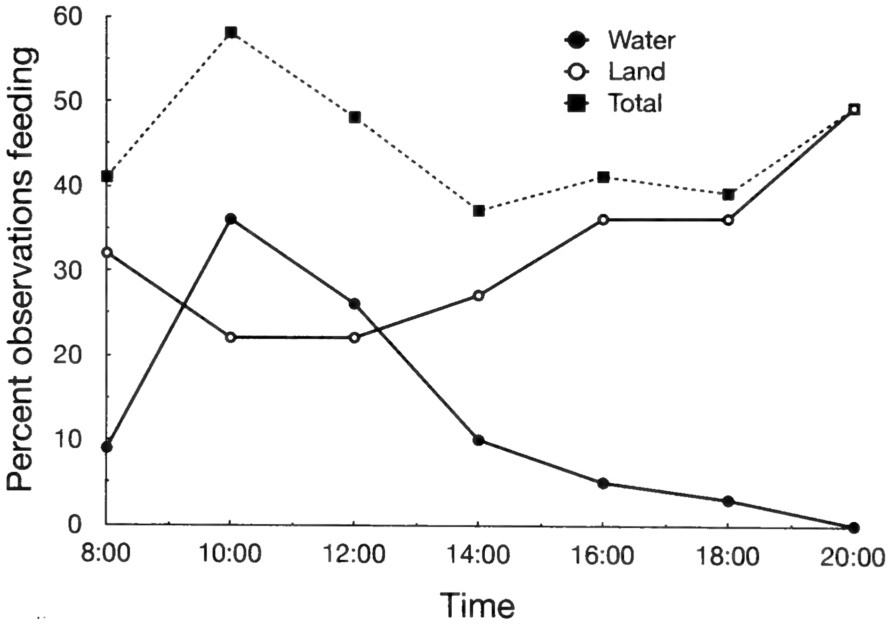

FIGURE 2. Activity budgets of approximately 7-week-old cygnets (*Cygnus buccinator*) in a managed pond at Aurora, Ontario. Values are the mean percentage of 15-s observations of cygnets feeding in water or on land from 4 to 12 July 2010.

strongly related to local snail abundance ($r = -0.885$, $P < 0.0001$). Thus, the cygnets more than satisfied their calcium requirements by eating snails. The absence of foraging in the natal pond in 2011 and 2012, when virtually only dead snails were available, suggests that the cygnets sought live snails, which contained more protein although less, but adequate, calcium. Their protein needs were satisfied by grazing on the lawn, as grasses contained 22.6% protein (Table 2).

Food abundance and swan response in 2011, 2012, and 2013

In 2011, the breeding pair hatched four cygnets, but two disappeared. In 2012, they hatched two cygnets, but one disappeared (see Lumsden 2013). Six cygnets hatched in 2013, but 2 disappeared.

In 2011, the snail population in the pond collapsed; the ratio of live to dead snails in samples was only 1:46. In 2012, it was 1:51 and, in July 2013, 1:222 (Table 1).

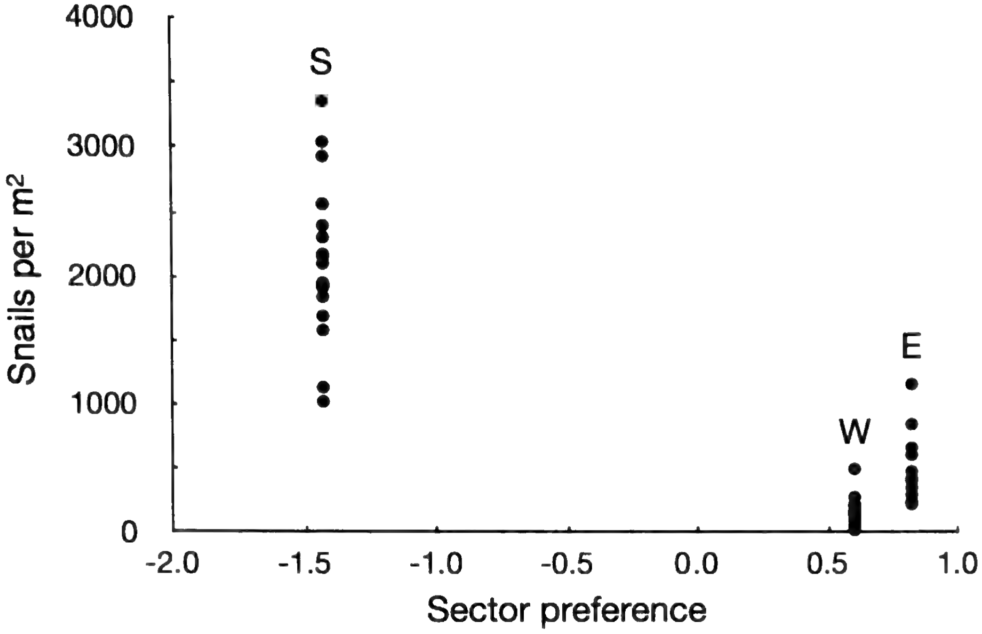

FIGURE 3. Relation between relative pond sector preference by approximately 11-week-old cygnets (*Cygnus buccinator*) in 2010 and the abundance of live and dead snails (per m^2 substrate) for Shore (S), West (W) and East (E) sectors. A preference value of 0 indicates that the sector is used in proportion to its available surface area. Negative values indicate greater relative preference for the sector, and positive values indicated greater avoidance.

TABLE 2. Nutrient analysis (dry mass basis) of duck grower pellets, grass, and snails in a pond in Aurora, Ontario, in 2010.

Food source	Protein, %	Calcium, %	Phosphorus, %	Magnesium, %
2010				
Duck grower pellets	15.0	0.85	0.70	0.05
Snails, live and dead	6.9	24.00	0.04	0.21
Grasses	22.6	0.68	0.34	0.18
2013				
Snails, live	10.3	18.20	0.21	0.09

Within 2 days of hatching, the broods moved to other ponds where they fed on *Lemna*. In 2011, they refused all offerings of duck grower pellets in July but returned to the lawn to graze and to the raft to roost. In late July 2012, the surviving cygnet accepted a single meal of duck grower pellets; in August, offered pellets were seldom eaten. In 2013, four of the six cygnets that hatched were fed on duck grower pellets three times a day. The adults appeared, initially, to feed on *Spirogyra*, attractive because it contains 23.3% protein.

Discussion

The drawdown of the pond had a significant effect on the quantity of invertebrates. Following drawdown and oxidation of the substrate, the restored water levels stimulated a significant pulse of snails. They were most plentiful in the Shore sector and least abundant in the West sector. These differences in snail abundance may have been influenced by the flow of fertile creek water superimposed on the effect of drawdown. The Shore sector, which was the only one with a burden of detritus on which snails also feed (Burch 1982), contained the greatest number of live snails (1434/m^2). Harper and Bolen (1996) and Collias and Collias (1963) have identified *Lemna* and the associated detritus as an important habitat for macroinvertebrates, such as snails. We suggest that detritus largely sustained the snails independent of drawdown, and cygnets exploited this abundance while it lasted.

Although the pond was drawn down for a second time in 2011, no pulse of snails developed. Because of flow-through, the fertile waters from the 2009 drawdown had presumably been flushed out. It is likely that no residual fertility was available for release in the substrate following the second drawdown.

Among birds, appetitive is an evolved searching behaviour that can be either innate or learned. The chicken's appetitive for calcium, for example, appears to result from learning, reinforced by taste and digestional satisfaction (Hughes and Wood-Gush 1971). However, Tordoff (2001) believed that calcium appetite has both innate and learned components.

The Aurora broods demonstrated a strong appetite for the most nutritious food available and rejected what was merely good, such as the duck grower pellets. Throughout their range, Trumpeter Swans use wetlands in which there appears to be enough food, but the quality as it appears to the swans may vary from acceptable to inadequate. Their selective foraging and appetitive skills ensure that both adults and cygnets locate foods that are sufficiently nutritious for growth and survival, especially in habitats susceptible to periodic droughts.

Acknowledgements

We thank Diana Lumsden for typing many drafts of this paper, Dr. Gerry Mackie, Department of Integrative Biology, University of Guelph, for identifying the pond invertebrates, and Angus Norman, who provided references.

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Received 15 October 2014
Accepted 27 July 2015

Movements of the Eastern Ribbonsnake (*Thamnophis sauritus*) in Nova Scotia

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Imlay, T. L., J. Saroli, T. B. Herman, and S. W. Mockford. 2015. Movements of the Eastern Ribbonsnake (*Thamnophis sauritus*) in Nova Scotia. Canadian Field-Naturalist 129(4): 379–385.

The disjunct Eastern Ribbonsnake (*Thamnophis sauritus*) population in southwest Nova Scotia is listed as "threatened" by the Committee on the Status of Endangered Wildlife in Canada. A study of the movements of the species at two lakeshore locations known to support a high density of Eastern Ribbonsnakes was undertaken in 2007 and 2008. Average seasonal movements at both sites ranged from 17 m to 84 m for juvenile snakes and 21 m to 130 m for adults; one neonate was recaptured during the study after travelling 32 m. The maximum distance travelled by an individual snake was 391 m in one season. The best-fit model to explain differences in daily movement patterns included year ($P = 0.041$), indicating that there is annual variation in the movements of this species. Low recapture rates precluded accurate estimates of home-range size, which varied roughly from 0.16 ha to 0.78 ha. Both movements and home ranges were larger than previously documented in Nova Scotia, but maximum distances travelled were consistent with a previous study in Michigan. Most documented movements were along the lakeshore within contiguous, suitable habitat. More work is needed to understand the frequency of large movements and triggers that initiate movements, e.g., changes in water levels, habitat suitability, or prey availability.

Key Words: Eastern Ribbonsnake; *Thamnophis sauritus*; Nova Scotia; movements; home range; site fidelity; recapture

Introduction

Movement patterns of a species are one of the most commonly studied factors in relation to conservation efforts as they often reflect spatial and temporal changes associated with life history stage or resource availability and use (Gregory *et al.* 1987). For example, seasonal movements often reflect a shift from summer foraging locations to hibernacula or other overwintering habitat (Larsen 1987; Webb and Shine 1997; Whiting *et al.* 1997). Movements may also reflect differences in microhabitat use by gravid and non-gravid individuals, which have different thermoregulatory needs and face different risks of predation (Shine 1979; Reinert and Kodrick 1982; Madsen 1984; Macartney *et al.* 1988; Charland and Gregory 1995; Webb and Shine 1997; Whiting *et al.* 1997; Stephenson *et al.* 2003; Harvey and Weatherhead 2006). Graves and Duvall (1993) noted that gravid Prairie Rattlesnakes (*Crotalus viridis viridis*) used rookeries that were often at a considerable distance from habitat used by non-gravid female and male snakes. Gravid Broad-headed Snakes (*Hoplocephalus bungaroides*) remained at the wintering habitat (exposed cliffs) during gestation when non-gravid and male snakes used nearby wooded habitats (Webb and Shine 1997). During ecdysis, snakes may also become more sedentary as lack of visual acuity can increase predation risk (Madsen 1984). Food availability can also drive movement patterns as snakes move from areas of low to high prey density (Whitaker and Shine 2003).

Site fidelity is often regarded as advantageous, as increased familiarity with habitat features enables individuals to avoid predators, forage, and thermoregulate effectively (Madsen 1984). Site fidelity has been observed in a variety of species across various spatial scales (Carpenter 1952; Barbour *et al.* 1969; Larsen 1987; Ciofi and Chelazzi 1994; Webb and Shine 1997; Stephenson *et al.* 2003; Whitaker and Shine 2003). Less mobile species may use the same rock or burrow in consecutive years (Webb and Shine 1997; Stephenson *et al.* 2003; Whitaker and Shine 2003). More mobile species may make long daily movements, but also return to the same shelter every evening (Ciofi and Chelazzi 1994).

The Eastern Ribbonsnake (*Thamnophis sauritus*) occurs in eastern North America from Florida to southern Quebec, with a disjunct population in southwest Nova Scotia (Gilhen 1984; Conant and Collins 1991; Desroches and Lepare 2004). Basic ecological knowledge of this species, including life history, distribution, and abundance, is lacking for much of its range. In this study, we examined the movement patterns of Eastern Ribbonsnakes at two sites in southwest Nova Scotia known to support high ribbonsnake densities, comparing daily movements of different age classes, sexes, and sites over 2 years.

Study Area

Grafton and Molega Lakes were chosen as study sites based on previous surveys that suggested a high density of Eastern Ribbonsnakes at these locations (Figure 1). Grafton Lake (44.3820°N, 65.2010°W), in Kejimkujik National Park and National Historic Site, is the site of an ongoing mark–recapture program to determine population size and structure that started in 2002. At Grafton Lake, the available ribbonsnake habitat was expanded

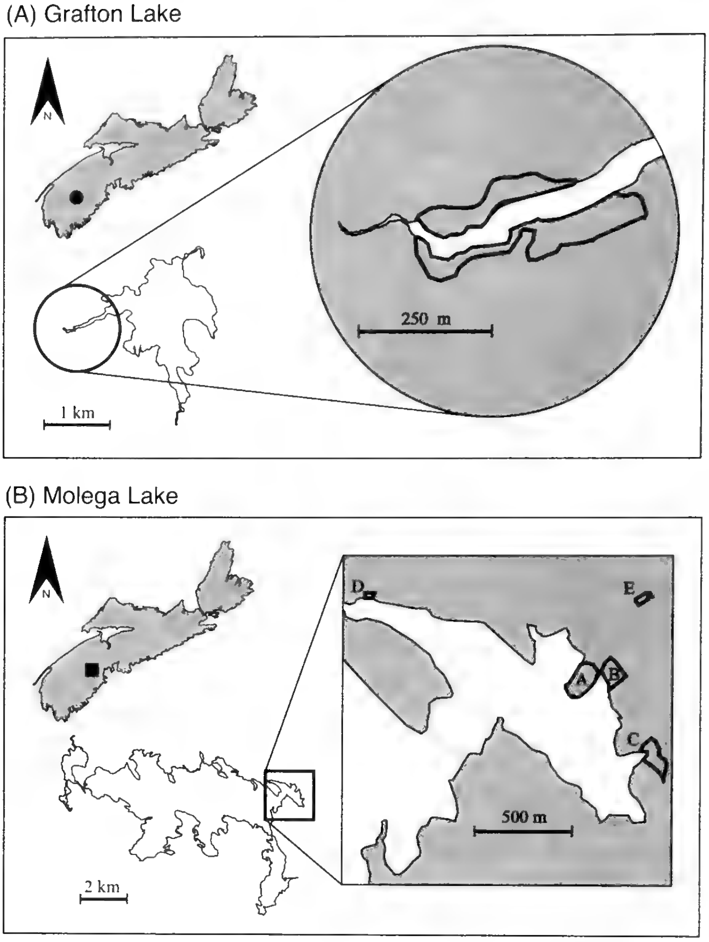

FIGURE 1. Location of Eastern Ribbonsnake (*Thamnophis sauritus*) study sites at (A) Grafton and (B) Molega Lakes, Nova Scotia. (A) In the detailed map, the study area at Grafton Lake is delineated by a bold line adjacent to the water. (B) Study sites are delineated by bold lines and labelled A to E.

in 1996 when a dam at Grafton Brook was removed. This resulted in a significant drop in water level in the lake and exposure of two large floodplains on either side of the brook. With the exception of several rapid stretches, water velocity in the brook is low. The floodplains support four distinct habitats (graminoid dominated areas, rocky areas, rocky areas with high density of woody shrubs, and areas with young conifers) and are surrounded by mixed deciduous and coniferous forest. In summer, pickerelweed (*Pontederia* spp.) and other aquatic vegetation (*Juncus* spp. and *Nuphar* spp.) are common along the edge of Grafton Brook. The current high density of ribbonsnakes at this site is attributed primarily to the large increase in suitable habitat resulting from dam removal.

At Molega Lake (44.3670°N, 64.7895°W) five distinct sampling zones were surveyed in an area known locally as Keddy's Cove (Figure 1B). The primary sampling zone (A) is a small peninsula, with shallow muddy banks along its base, leading to a small floodplain insulated from wind and waves by two conjoined eskers. A steeply banked causeway, apparently anthropogenic, along the peninsula is dominated by dense shrubs and bracken. A pair of small cottages on the peninsula are linked by a gravel driveway to the shoreline via the causeway. The central area of the peninsula surrounding the cottages consists of a well-tended yard, with dense shrubs and bracken lining the edges and shoreline. The floodplain of the esker is dominated by grasses; the vegetation on the eskers consists mainly of thick bracken and small trees.

Zone B, directly adjacent to and southeast of A, is a large muddy floodplain approximately 150 m across. When water level in the lake is high, the floodplain is mostly covered by water about 30–40 cm deep. Opposite the shoreline, a stream flows out to a section with permanently deeper water. Grasses and sedges line the shore close to the water, backed by taller shrubs, and finally trees marking the perimeter of the zone.

Zone C, approximately 500 m southeast of A, comprises a floodplain similar in structure to B but larger, approximately 250 m across. The flora is also similar to that of B, with grasses lining the muddy flooded shores and denser, larger sedges and bracken farther back from the waterline.

Zone D, approximately 1.3 km northwest of A, is a small inlet prone to flooding in low areas and mainly vegetated by tall shrubs and ferns. It has a rocky shoreline and heterogeneous relief. Small pools of still water, some up to a metre deep, dot the zone.

Zone E is approximately 500 m northeast of A. Unlike the other zones, it is inland and at a higher elevation. It is both spatially and structurally distinct from the other zones and comprises largely open woodland, with denser thickets of young Balsam Firs and pines. The substrate is primarily friable soil covered with conifer needles and coarse woody debris. A steeply banked stream, lined with exposed rocks, forms the southeast boundary of the zone, but was not included in visual surveys. No other open water occurred in the zone, and at no point did it become flooded.

Methods

Field Methods

We conducted visual surveys from April to November in 2007 and from May to August in 2008. At Molega Lake, zones A and B were both surveyed in 2007 and 2008; zones C, D, and E were added in 2008 when examination of the 2007 data suggested that zones A and B did not encompass the entirety of individual ribbonsnake movements. Grafton Lake was surveyed only in 2007 to allow more time for surveying at Molega Lake in 2008 and because additional data had been previously collected at the Grafton site. Over the 2 years, 965.2 h of observer effort was expended in visual surveys.

Visual surveys involved one or more researchers walking along transects running parallel to the water's edge. Typically, a distance of 5–10 m was maintained between researchers, although this varied with the habitat to be surveyed. Attempts were made to hand capture all ribbonsnakes that were observed. Locations of ribbonsnakes were recorded as UTM in NAD 83 using a handheld Garmin GPS 72 (Garmin Ltd., Schaffhausen, Switzerland); date and time were recorded for each observation. Snout-to-vent length (SVL) was measured for all captured snakes using a flexible, plastic measuring tape. Snakes were assigned to one of three age classes: neonate (born in August or September), juvenile, adult (SVL ≥ 37 cm). The smallest gravid female previously recorded in Nova Scotia had an SVL of 37 cm (Eastern Ribbonsnake (Atlantic Population) Recovery Team, unpublished data); this is consistent with other studies (e.g., Langford *et al.* 2011). The sex of adult snakes was assigned by examining the width of the tail posterior to the cloaca. Those with tails that tapered directly behind the cloaca were assigned as females. Those lacking an immediate taper behind the cloaca, because of the presumed presence of a hemipenis and those in which a hemipenis was observed during handling were assigned as males. Seven adults that were not consistently assigned to the same sex were noted as unknown sex during the analysis; in addition, all juvenile snakes were identified as unknown sex.

All captured snakes were given individual-specific marks. Adult and large juvenile snakes (SVL > 20 cm) were marked by clipping ventral scales in a unique code (Blanchard and Finster 1933). Small juvenile and neonate snakes were marked using a non-toxic permanent marker by drawing a series of circles posterior to the head and cloaca, and anterior to the cloaca. As clip codes were previously observed to regenerate during the active season (McNeil 2005) and marker codes fade, scale deformities and scars were also recorded and photographed to assist in identifying individual snakes. Shed ribbonsnake skins were also recorded as a ribbonsnake observation. Occasionally the individual could be identified from the skin if the ventral surface above the cloaca was intact, as the clip code was apparent.

Statistical Analysis

The mean and maximum number of captures, time between captures, straight-line distance between captures, and daily distance travelled between captures were calculated for each class from the recapture histories at both sites. A general linear model was used to examine the relation between daily distance travelled and the following variables: SVL, sex (male, female, or unknown), site (Grafton and Molega Lakes), and year (2007 and 2008). Daily distance travelled was determined by dividing the distance travelled between recaptures by the days between recaptures; a logarithmic transformation was used to normalize the data. Gravid female snakes are known to be less mobile than non-gravid females (e.g., Reinert and Kodrick 1982; Charland and Gregory 1995; Webb and Shine 1997); however, because it was not possible to determine the reproductive status of all females, this was not included as a variable in the model. A reverse step-wise regression procedure was used to select the best-fit model by comparing the small sample size correction for Akaike information criterion (AICc) and the AICc weight (Burnham and Anderson 2002).

ArcMap 9.2 (Environmental Sciences Research Institute, Redlands, California, USA) was used to calculate the distance between recaptures and the size of the home range of individual snakes with a minimum of five captures using a minimum convex polygon (Hawth's Analysis Tool version 3.27; Beyer, 2004). For snakes captured multiple times, home range size was calculated from the initial five captures and then additively with each additional capture. Increases in home range size with additional captures were used to determine the accuracy of the home range estimates for ribbonsnakes. Linear regression was used to determine whether there was a relation between the number of days between captures and the increase in home range size for snakes captured more than five times.

R version 1.7.2 (R Development Core Team 2012) was used for all statistical tests and to calculate summary statistics; means are presented with the standard deviation.

Results

In total, 136 ribbonsnakes were captured at least once at Grafton (54 in 2007) and Molega (50 in 2007 and 32 in 2008) Lakes during this study. Annual adult recapture rates did not exceed 60% (53–56% at Molega Lake and 48% at Grafton Lake) and juvenile rates ranged from 14–42% at Molega and 20% at Grafton Lakes (Table 1). Only a few individuals were captured in both years at Molega Lake. Of the 22 neonates marked, only one was recaptured during the study. An analysis of the time between recaptures revealed that 50% of recaptures at Grafton Lake and 70–82% of recaptures at Molega Lake occurred within 3 weeks of the previous capture (Figure 2).

Ribbonsnake movements varied with year, age class, and site. Throughout the season, movements of up to 136 m and 391 m were documented for juvenile and adult snakes, respectively (Table 2). However, average movements for juveniles (17.2–84.0 m) and adults (21.3–129.5 m) were typically less extensive. The only recaptured neonate snake moved 32 m between captures. The best-fit model to explain daily distance travelled included only year as a significant variable (P = 0.041) (Table 3). There was also strong support for the second best-fit model that included year and site (ΔAICc = 2.1) and some support for the inclusion of SVL (ΔAICc = 4.4). Ribbonsnake movements were

TABLE 1. Total number of recaptured Eastern Ribbonsnakes (*Thamnophis sauritus*), recapture rates, and time between recaptures for all age classes at Molega and Grafton Lakes, Nova Scotia.

Site	Year	Age	No. marked	No. recaptured (%)	Mean no. of captures (SD)	Max. no. of captures	Mean time between captures, days (SD)	Maximum time between captures, days
Molega	2007	Neonate	12	0	—	—	—	—
		Juvenile	21	3 (14)	2.3 (0.6)	3	15.8 (6.0)	33
		Adult	17	9 (53)	4.4 (2.4)	8	15.9 (17.4)	74
	2008	Neonate	3	0	—	—	—	—
		Juvenile	11	5 (42)	2.0 (0.0)	2	29.2 (39.6)	98
		Adult	18	10 (56)	2.7 (1.9)	8	22.1 (32.6)	112
	2007–2008*	Juvenile	21	3 (14)	2.0 (0.0)	3	—	292
		Adult	17	4 (24)	3.5 (3.1)	9	—	346
Grafton	2007	Neonate	7	1 (14)	—	2	—	1
		Juvenile	20	4 (20)	2.8 (1.0)	4	19.9 (16.6)	42
		Adult	27	13 (48)	2.8 (1.1)	5	43.9 (52.8)	190

*Includes only snakes marked in 2007 that were recaptured at least once in 2008.
Note: SD = standard deviation.

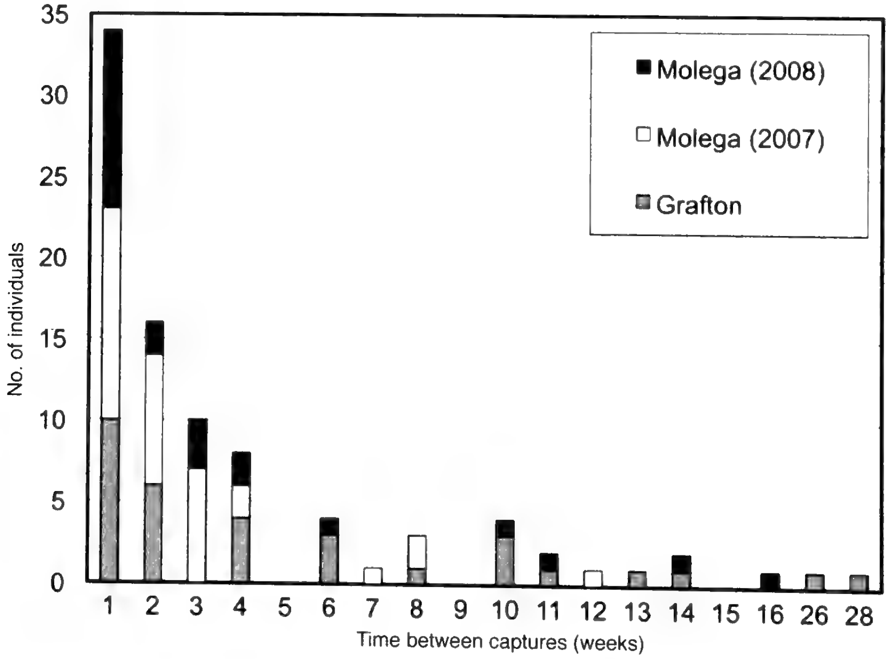

FIGURE 2. Time between captures of Eastern Ribbonsnakes (*Thamnophis sauritus*) at Grafton and Molega Lakes, Nova Scotia, in 2007 and 2008. Most recaptured snakes were caught within 3 weeks of the previous capture.

TABLE 2. Average and maximum movements of neonate, juvenile, and adult Eastern Ribbonsnakes (*Thamnophis sauritus*), at Molega and Grafton Lakes, Nova Scotia.

Site	Age and year	No.	Total distance travelled		Daily distance travelled	
			Mean, m (SD)	Maximum, m	Mean, m (SD)	Maximum, m
Molega	Juvenile 2007	4	47.2 (47.9)	130.0	14.6 (14.5)	36.0
	Juvenile 2008	5	84.0 (47.2)	136.1	3.3 (3.9)	9.2
	Adult 2007	30	62.7 (53.8)	196.4	10.2 (18.3)	94.3
	Adult 2008	18	21.3 (47.0)	112.1	4.8 (6.2)	18.0
Grafton	Neonate 2007	1	—	32.2	—	32.2
	Juvenile 2007	7	73.1 (16.6)	133.0	8.6 (9.2)	26.0
	Adult 2007	24	129.5 (114.8)	391.0	17.4 (54.9)	273.0

Note: SD = standard deviation.

TABLE 3. Best-fit model for Eastern Ribbonsnake (*Thamnophis sauritus*), movements at Grafton and Molega Lakes, Nova Scotia.

Model	AICc	*k*	ΔAICc	AICc weight
year	164.2	2	0.0	0.681
site* + year	166.3	4	2.1	0.234
site* + SVL* + year*	168.6	6	4.4	0.076
sex* + site* + SVL* + year*	172.8	7	8.7	0.009

*Not significant ($P < 0.05$).
Note: AICc = correction for Akaike information criterion, *k* = number of parameters, SVL = snout-to-vent length.

longer in 2007 than in 2008 for snakes at either Grafton or Molega Lakes (Figure 3).

The average home range size for snakes that were caught five or more times in a year was 0.43 ha (SD 0.27) (Table 4). With each successive capture of these snakes, home range size increased by 0.001–0.49 ha, suggesting that additional captures are still required to gain a more precise estimate of true home range size. For snakes captured more than five times, there was no significant relation between time between captures and increases in home range size ($R^2 = -0.125$, $P = 0.988$).

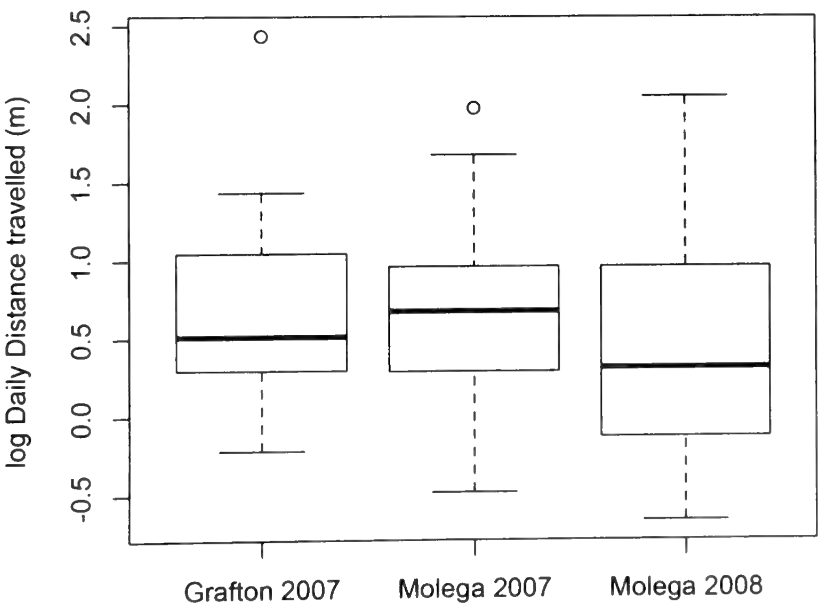

FIGURE 3. Distance travelled daily by Eastern Ribbonsnakes (*Thamnophis sauritus*) at Grafton and Molega Lakes, Nova Scotia, in 2007 and 2008. Daily distance travelled was greater in 2007 than 2008.

TABLE 4. Minimum convex polygon estimates of home range size of individual adult Eastern Ribbonsnakes (*Thamnophis sauritus*) that were recaptured five or more times in a year, ordered by snout-to-vent length (SVL), at Grafton and Molega Lakes, Nova Scotia.

Site	Year	Sex	SVL, cm	No. of captures	Home range, ha
Molega	2007	F	38	8	0.78
		M	39	7	0.64
		F	40	8	0.21
		F	44	5	0.18
	2008	F	39	8	0.16
Grafton	2007	M	39	5	0.23
		F	43	5	0.76
		F	51	5	0.49

Discussion

Both juvenile and adult snakes were documented travelling up to 100 m in 24 h; one adult at Grafton travelled nearly 400 m. In Michigan, the maximum daily distance travelled was 278 m (Carpenter 1952), consistent with our observations. In contrast, a study in Alabama documented daily movements up to 1 km for one male snake (Langford *et al.* 2011). The results of these studies also contrast with Bell *et al.* (2007), who reported more limited mobility in Eastern Ribbonsnakes in southwest Nova Scotia. However, movement data for this study were drawn primarily from gravid females, whose movements might have been reduced by both their reproductive status and the implanted radio-transmitters used to track them. Juvenile movements were within the range of adult movements, which is consistent with observations of juveniles or sub-adults in other species (Webb and Shine 1997; Bonnet *et al.* 1999).

Only one neonate was recaptured during the study at Grafton Lake; it travelled 32 m from the initial capture site in 1 day. In 2006, a neonate was recaptured at Molega Lake; it travelled 25.5 m in 4 days, similar to the Grafton observation (Eastern Ribbonsnake (Atlantic Population) Recovery Team, unpublished data). The lack of neonate recaptures at these sites is likely a result of the non-permanent marking technique and low detectability of snakes in this age class. More recaptures are needed to improve understanding of the movements and site fidelity of this age class, especially as high mortality from anthropogenic causes has been documented for neonates of other species (Bonnet *et al.* 1999).

Given the low recapture rates, it was difficult to estimate accurate home range size of adults. However, home range sizes were larger than the typical 50 m^2 noted by Bell *et al.* (2007). Although the home range estimates for adult males and females overlapped, females were recaptured more frequently than males, suggesting a sex-biased recapture rate. Gravid female snakes typically have smaller home ranges and reduced activity levels (Shine 1979; Reinert and Kodrick 1982; Madsen 1984; Macartney *et al.* 1988; Charland and Gregory 1995; Webb and Shine 1997; Whiting *et al.* 1997; Stephenson *et al.* 2003; Harvey and Weatherhead 2006); therefore, they may be encountered more frequently. Movements of male snakes may have extended beyond the sampling area in 2007 given that most recaptures occurred within 3 weeks of the initial capture, thus reducing the likelihood of recapture. Additional work is needed to determine the true extent of home ranges and whether area differs between the sexes and life-cycle stages (i.e., gestation).

Recapture rates during this study were low at both sites in 2007 and at Molega in 2008, with most recaptures occurring within 3 weeks of the previous capture. In 2008, additional wetlands and an upland area around zones A and B at Molega Lake were frequently surveyed in an attempt to document movements outside these zones. It should be noted that the low recapture rates might have reduced the likelihood of capturing marked snakes in these peripheral areas. Only four ribbonsnakes, and no marked individuals, were observed in these other survey areas, suggesting that although ribbonsnakes were capable of travelling long distances in a short period (as observed in 2007), they were not choosing to disperse long distances in that year.

Movements of the Concho Water Snake (*Nerodia harteri paucimaculata*) were largely driven by fluctuations in water levels that altered the availability of suitable habitat (Whiting *et al.* 1997). Whitaker and Shine (2003) noted that movements of Eastern Brown Snakes (*Pseudonaja textilis*) were likely driven by prey availability. Mean distances travelled by adults at Molega Lake in 2008 were considerably lower than in 2007, indicating annual variation in movements. Because the lakeshore wetland environment of ribbonsnakes is highly dynamic, it is possible that the extent of movements changes with changing water levels and availability of suitable habitat or prey (e.g., small amphibians and minnows; Carpenter 1952; Bell *et al.* 2007).

The cryptic behaviour of Eastern Ribbonsnakes and the densely vegetated wetland habitats with which the species is associated make the species difficult to study. Although large movements have been documented, it is unknown how frequently these movements occur and what changes in the environment trigger them. Given the species' current conservation status as threatened in Nova Scotia, special concern in Ontario, and declining in several states in the United States (Harding 1997; COSEWIC 2002), we recommend that future work determine the frequency and trigger for large movements and assess the risk of mortality of individuals undertaking these movements to aid recovery planning.

Acknowledgements

First and foremost, we thank the many cottage owners on Molega Lake who granted permission to access their property for surveys and were enthusiastic about the project. J. McNeil provided invaluable expertise with data management. C. Wagner, R. Thibodeau, A.-A.

Hallé, J. Lefebvre, J. Brunt, B. McNeil, B. Caverhill, D. Smith, H. Reed, and many other volunteers devoted time to ribbonsnake surveys. Christine McLauchlan provided assistance with maps. The support of S. Flemming and the staff at Kejimkujik National Park and National Historic Site is also greatly appreciated. Animal use proposals were reviewed and approved by the Acadia University Animal Care Committee. Fieldwork was conducted under approved permits from the Nova Scotia Department of Natural Resources and Kejimkujik National Park and National Historic Site. Finally, we would like to acknowledge financial support from Acadia University, Species at Risk Recovery Action and Education Fund of Parks Canada, and the Habitat Stewardship Program of Environment Canada.

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Received 7 February 2013
Accepted 24 October 2015

Recent Occurrences of Wild-origin Wolves (*Canis* spp.) in Canada South of the St. Lawrence River Revealed by Stable Isotope and Genetic Analysis

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McAlpine, Donald F., David X. Soto, Linda Y. Rutledge, Tyler J. Wheeldon, Bradley N. White, James P. Goltz, and Joseph Kennedy. 2015. Recent occurrences of wild-origin wolves (*Canis* spp.) in Canada south of the St. Lawrence River revealed by stable isotope and genetic analysis. Canadian Field-Naturalist 129(4): 386–394.

A free-ranging canid killed near Caraquet, New Brunswick, Canada, in 2012 exhibited a mitochondrial DNA sequence of Gray Wolf (*Canis lupus*) origin and a Y-chromosome haplotype of Eastern Wolf (*C. lycaon*) origin. The animal, which is the first wolf recorded in New Brunswick since 1862, was identified as a Gray–Eastern Wolf hybrid (*C. lupus* × *C. lycaon*) based on analysis of its autosomal microsatellite genotype. Stable carbon isotope values ($\delta^{13}C$) suggest that the Caraquet wolf was of wild origin. Likewise, $\delta^{13}C$ analysis suggests that a wolf–coyote hybrid killed in Quebec south of the St. Lawrence River in 2002 was also of wild origin. However, $\delta^{13}C$ values for a wolf from the same region in 2006 suggest that this animal spent most of its life feeding predominantly on non-wild-source food items. Recent occurrences of wild-origin animals south of the St. Lawrence River demonstrate that wolves are capable of dispersal to formerly occupied areas in southeastern Canada and the United States. However, limited natural dispersal alone will likely not be sufficient to re-establish wolves in northeastern North America.

Key Words: Gray Wolf; *Canis lupus*; Eastern Wolf; *Canis lycaon*; Coyote; *Canis latrans*; conservation; stable isotopes; genetic analysis; New Brunswick; Quebec; St. Lawrence River

Introduction

Information concerning the history of the wolf (*Canis* spp.) in Maritime Canada (New Brunswick, Nova Scotia, and Prince Edward Island) is sparse. The scant literature suggests that wolves were rare in the region at the time of European settlement in the early 1600s (Ganong 1908; Scott and Hebda 2004; Sobey 2007). Reports of wolves increased in New Brunswick starting in 1774 and peaked during 1840–1860 (Ganong 1908; Parker 1995). Reports of occurrence in Nova Scotia are likewise limited, with the last known wolf in Nova Scotia killed for bounty in 1845–1847 (Ganong 1908; Scott and Hebda 2004). A bounty on wolves was introduced in New Brunswick in 1792, apparently in response to the loss of domestic sheep; a further New Brunswick bounty on wolves was in effect from 1858 to 1870, with the last bounties paid for three wolves killed in 1862 (Ganong 1908). Historic information on the status of wolves on Prince Edward Island is anecdotal and limited, but suggests that animals may have moved onto the Island over the ice from adjacent New Brunswick and Nova Scotia (Sobey 2007). In 1900, Thaddeus Thurber collected mammals across parts of northern New Brunswick and southern Quebec, reporting at that time that wolves were rare throughout the region, with only a few still present in Quebec south of the St. Lawrence River outside the Gaspé (Elliot 1901). Although wolves may have continued to occur in New Brunswick until 1921 (Lohr and Ballard 1996), Ganong (1908) considered the wolf nearly extirpated in the province by 1867.

Wolves were, therefore, never common in Maritime Canada, and Lohr and Ballard (1996) concluded that there was insufficient historical information to ascertain whether New Brunswick ever supported a minimum viable wolf population. By the early 1970s, following an eastward range expansion, Coyote (*Canis latrans*) were abundant in New Brunswick. Recent evidence suggests that Coyotes now inhabiting eastern Canada are hybrid, having interbred with wolves as they moved east (Kays *et al.* 2010). Regardless, it is now more than a century since any canid deemed to be a wolf has been confirmed to be free-ranging in New Brunswick. Thus, it is significant that in the late winter of 2012 a large wolf-like canid was shot and killed in northern New Brunswick.

Over the past several decades, the few free-ranging wolves reported south of the St. Lawrence River in Canada and through the northeastern United States have generally been considered of wild origin (Elder 2000; Villemure and Jolicoeur 2004). However, Kays and Feranec (2011) recently determined that among eight animals collected in New England, most were of captive origin, although three were likely of wild origin. In addition, the assignment of free-ranging animals to specific types within the genus *Canis*, especially in regions of hybridization among Coyotes, domestic dogs, and wolves, is rarely obvious phenotypically (Chambers *et al.* 2012). The origin and identity of wolf-like canids in the northeastern United States and Canada south of the St. Lawrence River can, therefore, not be assumed, although such occurrences could be significant to potential wolf re-introduction or re-establishment in these regions.

Here we identify the genetic status and origin (wild versus captive) of a purported wolf shot in New Brunswick in 2012. We also report on the origin of two wolves from Quebec south of the St. Lawrence River killed in 2002 and 2006 and discuss the significance of these results. Acknowledging that wolf taxonomy in North America remains controversial, we follow a three-species model (Chambers *et al.* 2012; Rutledge *et al.* 2012) that includes the Gray Wolf (*Canis lupus*), Eastern Wolf (*C. lycaon*), and Coyote (*C. latrans*), and their hybrids, rather than the more traditional two-species approach, *C. lupus* and *C. latrans* (Koblmüller *et al.* 2009; vonHoldt *et al.* 2011).

Methods

Collection and Necropsy

On 6 April 2012, a large canid was shot at a bait station in a regenerating clear-cut forest about 3 km southwest of Caraquet (47.7280°N, 64.9474°W; Figure 1), in northwest New Brunswick, Canada. New Brunswick Department of Natural Resources (NB DNR) personnel collected tissue for genetic analysis and the carcass of the animal was subsequently turned over to NB DNR. A full necropsy of the animal by a qualified veterinary pathologist (JPG) was performed; standard external measurements and body mass were recorded and alimentary tract contents were collected for later examination. The skeleton and taxidermied hide were deposited in the New Brunswick Museum (NBM M11985). We used the tooth wear criteria of Gipson *et al.* (2000) developed for Gray Wolves, in conjunction with a series of wolf skulls from northern Quebec and Labrador deposited in the NBM mammal collection that had been aged by tooth-sectioning (Parker and Luttich 1986), to estimate the age of the animal. We refer to this specimen hereafter as the "Caraquet wolf."

Genetic Analysis

DNA was extracted from tongue tissue of the Caraquet wolf with a Qiagen DNeasy Blood and Tissue Kit (Qiagen Inc., Toronto, Ontario, Canada). Maternal, paternal, and bi-parental genetic markers were investigated for species identification. The mitochondrial DNA (mtDNA) control region was amplified as in Wheeldon *et al.* (2010), and the polymerase chain reaction product was sequenced in both forward and reverse directions on an ABI3730 DNA analyzer (Life Technologies, Burlington, Ontario, Canada). Sequences were edited in MEGA (version 5; Tamura *et al.* 2011), and the consensus sequence was assigned a specific haplotype based on a search of the National Centre for Biotechnology Information sequence database using the Basic Local Alignment Search Tool (BLAST) and comparison with previously described sequences (Wilson *et al.* 2000).

Four Y-chromosome microsatellite loci and 12 autosomal microsatellite loci were genotyped as in Wheeldon *et al.* (2010). The Y-chromosome microsatellite genotype was combined into a haplotype. The autosomal microsatellite genotype of the Caraquet wolf was analyzed in the Bayesian-clustering program STRUCTURE (version 2.3; Pritchard *et al.* 2000; Hubisz *et al.* 2009) using default settings (i.e., F-model, infer alpha), including genotypes from five reference populations (data from Wheeldon 2009; Wheeldon *et al.* 2013): Coyotes from southeastern Ontario (n = 100); Eastern Wolves from Algonquin Provincial Park, Ontario (n = 62); Gray–Eastern Wolf hybrids from northeastern Ontario (n = 62; which are known to cluster together with wolves from parts of Quebec; Wheeldon 2009); Gray Wolves from Northwest Territories (n = 55); and Domestic Dogs (*C. lupus familiaris*; n = 75). The admixture model of STRUCTURE was run five times assuming $K = 5$ for 10^6 iterations following an initial burn-in of 10^5 iterations and Q values for the Caraquet canid were averaged. We used an exclusion test with 10 000 simulated genotypes and the frequencies-based method (Paetkau *et al.* 1995, 2004) in GENECLASS (version 2; Piry *et al.* 2004) to determine the probability of the Caraquet wolf originating from each of the five reference populations.

Stable Isotope Analyses

Stable isotopes are increasingly used in wildlife ecology and forensics to determine the geographic origin or diet of animals (Bowen *et al.* 2005; Moore and Semmens 2008; Hobson *et al.* 2012). Here, we used a multi-tissue stable isotope approach to determine the wild versus captive origin of wolf samples based on short- and long-term trophic history, following the method of Kays and Feranec (2011). The method assumes that captive-origin animals have been fed a diet derived from C_4 plant material (i.e., corn), whereas wild-origin wolves have fed on tissue derived from C_3 plants, which are dominant in northeastern North America. Free-ranging urban or suburban canids may rely on food from domestic sources (i.e., C_4) to some degree. This should be reflected in a carbon stable isotope signature that is intermediate between those of captive and wild animals. As isotope turnover rates vary among tissues, the stable isotope composition of different tissues can incorporate trophic information from specific time periods (Tieszen *et al.* 1983). For mammals, hair samples provide isotopic data since the last molt, while bone should provide information over the entire life of a canid (Kays and Feranec 2011). Kays and Feranec (2011) acknowledge that interpreting such signatures with the limited data currently available can sometimes present challenges, and they review the limitations and caveats of the approach. They also investigated the use of nitrogen stable isotopes to discriminate between wild- and captive-origin wolves, but did not find this useful.

Collagen was extracted from bone (caudal vertebrae, scapula, and metatarsals) and hair of the Caraquet wolf in the manner of Kays and Feranec (2011). To place the Caraquet wolf in a broader context, we also obtained hair and bone for stable carbon isotope analysis ($\delta^{13}C$) from two wolves killed in 2002 and 2006 in Quebec south of the St. Lawrence (Figure 1).

The 29.1-kg male "Lingwick wolf" was snared in January 2002 near the village of Sainte-Marguerite-de-Lingwick (45.6042°N, 71.2875°W). Villemure and Jolicoeur (2004) reported that the mtDNA profile for this animal was consistent with an Eastern Wolf–Coyote hybrid, the microsatellite genotype suggesting 95.0% shared ancestry with Eastern Wolf from Algonquin Provincial Park, Ontario. On this basis, Villemure and Jolicoeur (2004) identified the animal as an Eastern

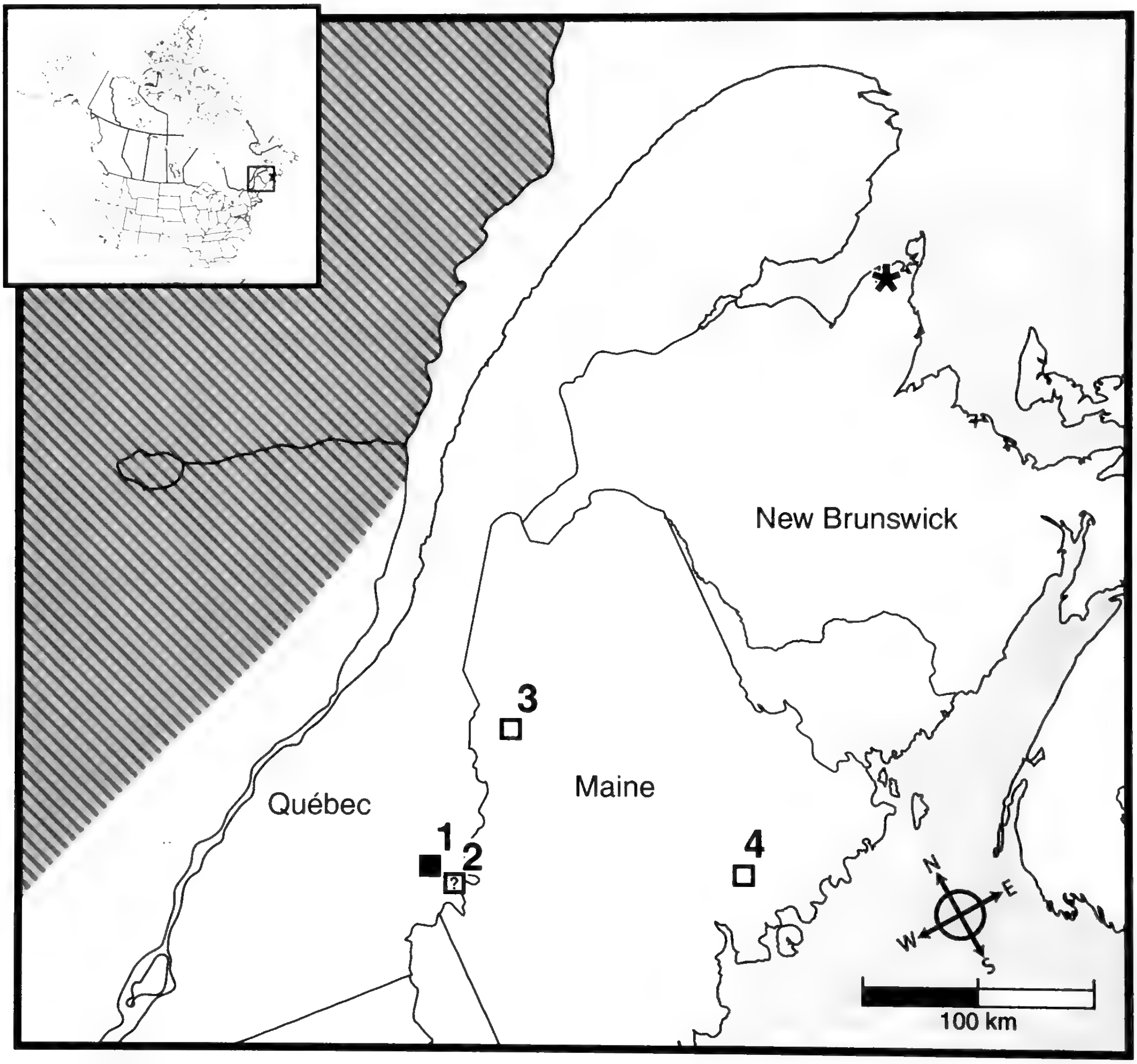

FIGURE 1. Collection location of the Caraquet wolf (*), a Gray Eastern Wolf hybrid (*Canis lupus* × *C. lycaon*), and extralimital records of wolves in adjacent Maine and Quebec determined by $\delta^{13}C$ to be wild (■), domestic (□), or of unknown origin (?). Wolves 3 and 4 are the most northerly records analyzed by Kays and Feranec (2011). The stippled area marks the southeastern margin of the current distribution of Gray and Eastern Wolves and their hybrids (*C. lupus*, *C. lycaon*, *C. lupus* × *C. lycaon*) in Quebec. 1 = Lingwick wolf, 2 = Sainte-Marguerite wolf, 3 = Museum of Comparative Zoology, Harvard (MCZ) 62506, 4 = MCZ 62507.

Wolf. In a more recent study using 12 nuclear markers, this animal clustered with Quebec Coyotes (Stronen *et al.* 2012). However, the sample size of Eastern Wolves from Algonquin Park in Stronen *et al.* (2012) was insufficient to identify a distinct cluster of Eastern Wolves in the program STRUCTURE. The Lingwick sample may, therefore, have been inaccurately assigned and A. V. Stronen (Aalborg University, Denmark, personal communication) has acknowledged that this animal should be considered a wolf–coyote hybrid. Although the skull of the Lingwick canid is decidedly smaller and less robust than that of the Caraquet wolf (or the Sainte-Marguerite wolf, see below; Figure 2), the body weight of this animal is above the mean for male Coyote, Coyote–Eastern Wolf hybrids, or Eastern Wolves provided by Benson *et al.* (2012). The skull and mounted skin of this animal are now in the Musée de la nature et des sciences in Sherbrooke, Quebec (accession no. 2003.2).

The 48.6-kg "Sainte-Marguerite wolf" was trapped in November 2006 near Sainte-Marguerite-de-Beauce (45.514°N, 70.9415°W) and has been identified genetically as an Eastern–Gray Wolf hybrid (J.-F. Dumont, Québec Ministère des Forêts, de la Faune et des Parcs, personal communication); the mounted skin is in a private collection and the skull is held by the Ministère des Ressources naturelles et de la Faune, Quebec.

Bone samples were decalcified using 0.5 N HCl at room temperature for 24–48 h. Samples were rinsed with distilled water and then decanted once the mineral portion of the bone was fully dissolved. Lipids were extracted in a 2:1 (v/v) chloroform:methanol solution and the resulting bone collagen was oven dried. Hair samples were washed in the same solution to remove surface oils and air dried. Samples (about 1 mg) were analyzed for $\delta^{13}C$ using a continuous flow isotope-ratio mass spectrometer (Thermo-Finnigan, Bremen, Germany) at the Stable Isotopes in Nature Laboratory, Fredericton, New Brunswick. Carbon isotope measurements were expressed as isotope delta (δ) in parts per thousand (‰) relative to the international standard, Vienna Pee Dee Belemnite. Isotope values were normalized using in-house standards calibrated against International Atomic Energy Agency reference materials. Analytical precision, estimated by repeated analyses of laboratory standards, was better than ± 0.2‰.

Canid $\delta^{13}C$ values were adjusted using the same diet-tissue discrimination values that Kays and Feranec (2011) applied to wolves and Coyotes from the northeastern United States (+5.0‰ for bone collagen and +2.6‰ for hair; Roth and Hobson 2000). Here, we assume that the isotopic composition of the wild diet of canids in eastern Canada is similar to that of canids in the northeastern United States. Although potential

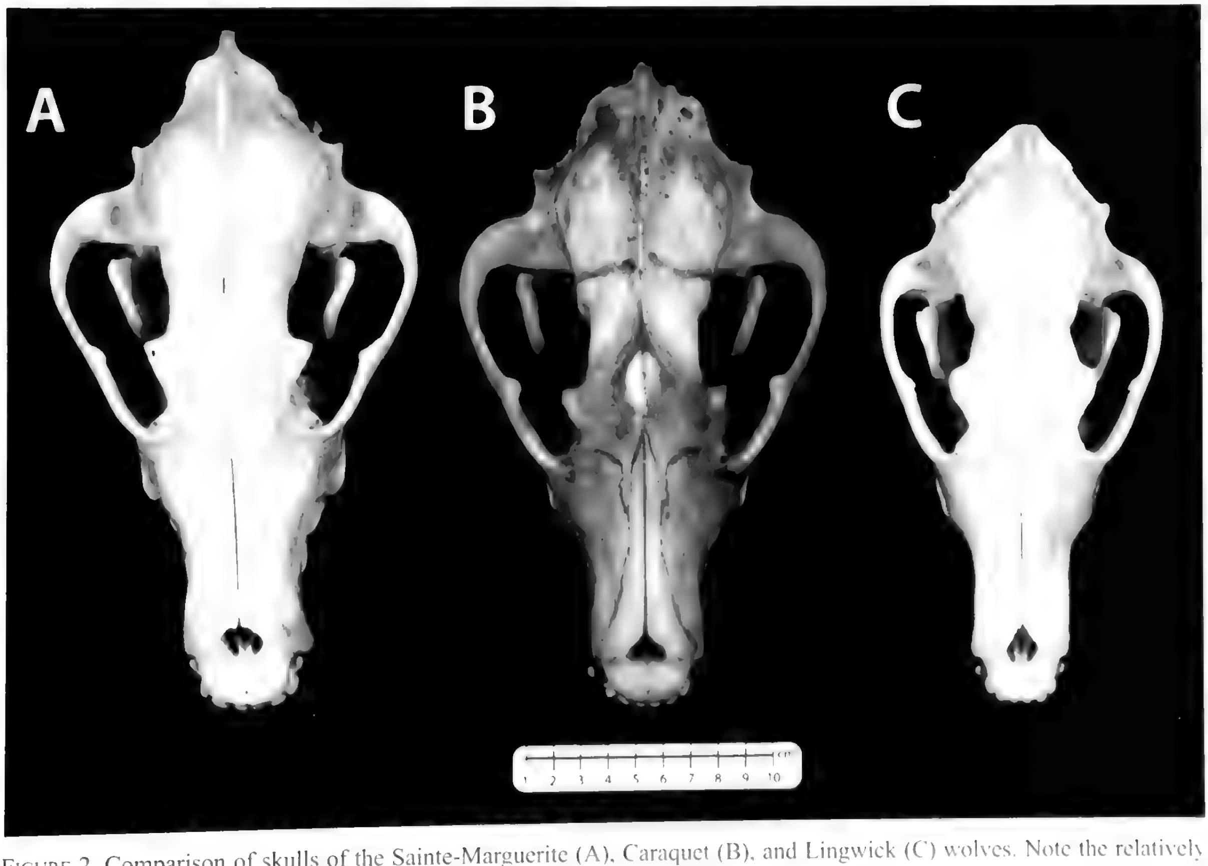

Figure 2. Comparison of skulls of the Sainte-Marguerite (A), Caraquet (B), and Lingwick (C) wolves. Note the relatively smaller size and less robust character of C, an Eastern Wolf–Coyote hybrid (*Canis lycaon* × *C. latrans*) compared with A and B, both Gray–Eastern Wolf hybrids (*C. lupus* × *C. lycaon*). Photo: New Brunswick Museum.

regional isotopic variation could introduce uncertainty, we believe it should be negligible given that eastern Canada and New England are geographically proximate and that Kays and Feranec (2011) found relatively good separation in isotopic values between wild and captive canid diets.

We categorized New Brunswick and Quebec wolves as "wild" or "captive" using an assignment test based on likelihood analysis (Rogers *et al.* 2012). From each measured wolf $\delta^{13}C$ value, we depicted the likely origin of individuals and summarized the likelihood of origin for each wolf based on the average probability across our replicate samples. The likelihood that a wolf sample originated from a captive versus wild animal was determined by $f(y^* \mid \mu_f, \sigma_f)$, assessing a normal probability density function as follows:

$$f(y^*|\mu_f, \sigma_f) = \frac{1}{\sqrt{2\pi\sigma_f^2}} \exp\left[-\frac{1}{2\sigma_f^2}(y^* - \mu_f)^2\right]$$

for each wolf subsample (y^*), given the expected mean (μ_f) and standard deviation (σ_f) of $\delta^{13}C$ for individuals growing their tissues on domestic food (mean = −18.2, standard deviation [SD] = 3.4 for commercial meat and dog foods typically given to captive canids) or wild food sources (mean = −27.8, SD = 1.8 for medium and large mammals and wild fruits that generally dominate their natural diet) analyzed by Kays and Feranec (2011). Thus, values from replicate samples for each wolf showed a probability of origin for both domestic and wild food sources, with the highest values of $f(y^* \mid \mu_f, \sigma_f)$ indicating the greatest likelihood of the animal being associated with that food source.

Results

Collection and Necropsy

The Caraquet wolf (Figure 3) was a male; testes were scrotal and measured 40.6 mm by 29.1 mm. Shortly after death, the animal weighed 39.9 kg. Tooth wear suggests that it was 3–4 years old at time of death. Measurements for the animal were as follows: total length 1573 mm, tail vertebrae 397 mm, hind foot 278 mm, ear 107.4 mm. Physically, the animal was in good body condition; it was negative for mange and carried 12.2–22.6 mm of extra-visceral body fat across the lateral pelvic region, about 2 mm over the ribs, and 819.2 g of visceral fat. Stomach contents (266.4 g wet

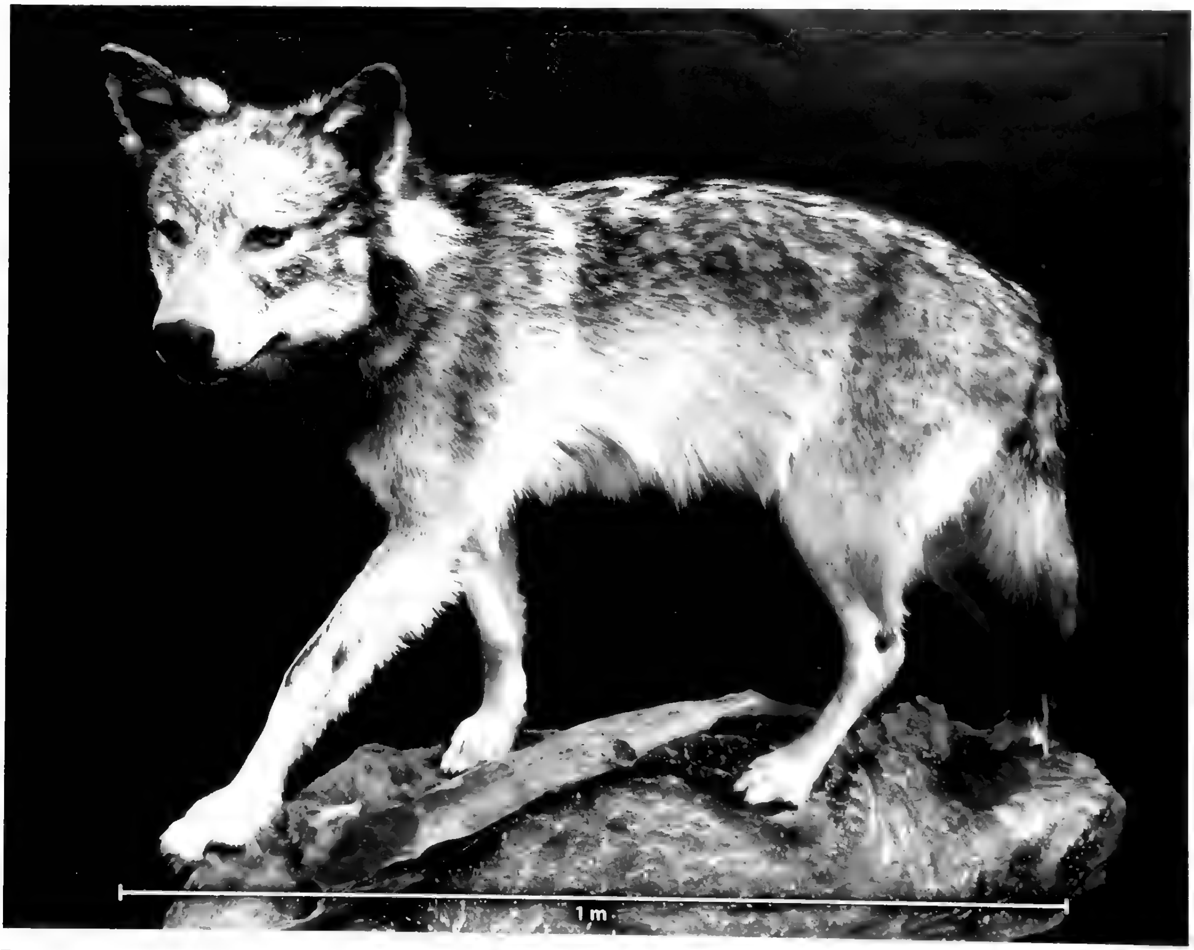

FIGURE 3. Taxidermied skin of the Caraquet wolf, a Gray Eastern Wolf hybrid (*Canis lupus* × *C. lycaon*) (NBM M11985). Photo: New Brunswick Museum.

weight) consisted mostly of pig meat from the bait. However, some residual hairs in the stomach and a 20.4-g (wet weight) fecal pellet of hair proved to be Moose (*Alces americanus*). Mature taenid cestodes were present in the intestine.

Genetic Analysis

Genetic analysis identified the Caraquet wolf as a Gray–Eastern Wolf hybrid. The mtDNA sequence (C22; Wilson *et al.* 2000) was of Gray Wolf origin and the Y-chromosome haplotype (AA; Wilson *et al.* 2012) was of Eastern Wolf origin. STRUCTURE assigned the Caraquet wolf 96% to the northeastern Ontario Gray–Eastern Wolf hybrid reference population and GENECLASS analysis excluded (i.e., $P < 0.01$) all populations except northeastern Ontario Gray–Eastern Wolf hybrids ($P = 0.305$) as a probable population of origin.

Stable Isotope Analyses

The δ^{13}C value for bone collagen of −26.85 ± 0.38 for the Caraquet wolf clearly places it within the "wild" category (range −30.2 to −24.6) of Kays and Feranec (2011), although hair samples hint at some reliance on domestic food sources since the last molt (Table 1). The Lingwick wolf, with a δ^{13}C value for bone collagen of −28.34 ± 0.16 is also classified as of wild origin. Hair samples from the Lingwick wolf likewise suggest an animal that fed on wild food sources since its last molt. Analysis of bone collagen from the Saint-Marguerite wolf suggests that this animal spent most of its life subsisting on prey that included substantial domestic food sources, and hair samples strongly suggest that this animal had been feeding on or was fed largely domestic food sources since its last molt. Although the overall δ^{13}C value for the Saint-Marguerite wolf, −23.34 ± 1.02, is ambiguous in terms of categorizing this animal as a once-captive or a free-ranging urban animal, it strongly suggests that this wolf did not spend most of its life as a free-ranging wild animal. Likelihood-based assignment methods support these characterizations (Table 1).

TABLE 1. Stable carbon isotope analysis of bone collagen and hair samples from New Brunswick and Quebec wolves south of the St. Lawrence River. Trophic discrimination values of δ^{13}C +5.0‰ for bone collagen; +2.6‰ for hair.

Sample source	Mean δ^{13}C ± SD	Likelihood of wild origin, %	Number of replicates
Caraquet wolf			
Collagen	−26.85 ± 0.38	98	6
Hair	−24.52 ± 0.18	67	4
All samples	−25.92 ± 1.19		10
Lingwick wolf			
Collagen	−28.34 ± 0.16	99	6
Hair	−26.79 ± 0.16	98	3
All samples	−27.82 ± 0.79		9
Sainte-Marguerite wolf			
Collagen	−24.26 ± 0.13	57	6
Hair	−22.42 ± 0.47	6	6
All samples	−23.34 ± 1.02		12

Discussion

Regardless of the historical genetic composition of Maritime wolves, the Caraquet wolf is the first free-ranging, wild-origin wolf recorded in New Brunswick since 1862, presumably dispersing south to the province from northeastern Ontario or western Quebec north of the St. Lawrence River. Wolves were extirpated from Maritime Canada by about 1900 (Harrison and Chapin 1998) and their possible re-establishment, whether by natural or assisted means, is controversial (Lohr *et al.* 1996; Nie 2001; Williams *et al.* 2002; Musiani and Paquet 2004). However, determining whether wolves outside their current distributional range represent the vanguard of re-establishment can be difficult. Such animals may represent nothing more than isolated occurrences of once-captive wolves or domesticated wolf–dog hybrids (Prendergast 1989; Kays and Feranec 2011), particularly as an estimated 300 000 wolf–dog hybrids are kept as companion animals in the United States (Fischer 2003). Complicating the sociopolitical issues surrounding wolf re-establishment has been an unresolved taxonomy (Chambers *et al.* 2012), lack of information on historical distribution of forms (Wilson *et al.* 2003; Rutledge 2010a), and possible contemporary hybridization among wolves, coyotes, and dogs (vonHoldt *et al.* 2011; Stronen *et al.* 2012; Monzón *et al.* 2013; Way 2013).

The literature suggests that wolves (of unknown genotype) were not common in Maritime Canada in the past, so it is not surprising that historical wolf specimens from New Brunswick do not appear to exist (Lohr and Ballard 1996). Wilson *et al.* (2000) include Maritime Canada within the historical range of the Gray Wolf. Wheeldon and White (2009) suggest that admixing of the Gray Wolf and the Eastern Wolf may pre-date European settlement in the western Great Lakes region, whereas Wilson *et al.* (2003) showed that historical samples from New York and Maine carried only Eastern Wolf mtDNA. Based on 16th century archaeological remains, Rutledge *et al.* (2010a) suggest that the Eastern Wolf, or perhaps an Eastern–Gray Wolf hybrid occupied the eastern temperate forest before European arrival. Kyle *et al.* (2006) state that after European settlement, it was the Gray Wolf that was extirpated from southeastern Ontario and Quebec; this was followed by land clearing, changes in forest cover, and the concomitant movement of the Eastern Wolf northward with White-tailed Deer (*Odocoileus virginianus*).

Unfortunately, none of this information resolves questions about the genetic makeup of the wolves that may have occupied New Brunswick historically. Harrison and Chapin (1998) and Wydeven *et al.* (1998) felt it was unclear whether wolves could recolonize available habitat in northeastern North America without human assistance and recommended a re-introduction program. Although Harrison and Chapin (1998) note that low human population and the extensive forests of northern New Brunswick provide suitable habitat for wolves, they also suggest that the St. Lawrence River and associated human development may present barriers to wolf dispersal south from Ontario and Quebec. Likewise, Larivière *et al.* (2000) were uncertain whether individual wolves from populations in Quebec north of the St. Lawrence River might disperse to available wolf habitat in the northeastern United States.

Until 2002, wolves had not been reported in the wild in Canada south of the St. Lawrence River for more than a century (Wydeven *et al.* 1998; Villemure and Jolicoeur 2004). Nonetheless, $\delta^{13}C$ values suggest that the Caraquet and Lingwick wolves were of wild origin, indicating that wolves are capable of dispersing from north of the St. Lawrence River into southern Quebec and New Brunswick and probably the northeastern United States, in spite of natural and human barriers. Kays and Feranec (2011) also report that some free-ranging wolves in the northeastern United States appear to be of wild origin based on $\delta^{13}C$ values. Furthermore, in the course of our work, we were made aware of other purported (and assumed wild) wolves from Quebec south of the St. Lawrence River and New England (M. Hénault, Québec Ministère des Forêts, de la Faune et des Parcs, personal communication; M. McCollough, Endangered Species Specialist, United States Fish and Wildlife Service, personal communication; Monzón 2012), in addition to those examined by Kays and Feranec (2011).

The outcome of any future wolf dispersal into New Brunswick or New England is unclear. Although Coyotes in the east will readily interbreed with the Eastern Wolf (Kyle *et al.* 2006; Rutledge *et al.* 2010b), such hybridization occurs more rarely with Gray–Eastern Wolf hybrids (Wheeldon and Patterson 2012). Kyle *et al.* (2006) note that, although hybridization may be reducing the distinctiveness of the Eastern Wolf, it may also enhance the adaptive potential of wolves. Conversely, Coyote hybridization with wolves appears to have enhanced the adaptive ability of Coyotes in the northeast (Kays *et al.* 2010). Kyle *et al.* (2006) and Way (2013) both suggest that a Gray–Eastern Wolf hybrid is a more efficient predator of Moose than a Coyote–Eastern Wolf hybrid, which is adapted to prey on deer. Moose is the predominant ungulate in northern New Brunswick (Forbes *et al.* 2010).

Wydeven *et al.* (1998) observed that wolves in southern Ontario and Quebec appeared to be heavily exploited. Together with the fate of the Lingwick, Saint-Marguerite, and Caraquet wolves, this suggests that mortality among wolves dispersing into regions south of the St. Lawrence River may be high. In light of possible high mortality and the dense network of roads adjacent to the St. Lawrence River (well above the < 0.70 km/km^2 selected by Harrison and Chapin [1998] as a proxy for maximum levels of human presence compatible with wolf habitat), natural dispersal alone may be insufficient to re-establish the wolf in the northeast. Nonetheless, the importance of individual dispersers to the evolutionary potential of whatever wolf-like phenotype populates the region south of the St. Lawrence River in the future should not be underestimated (Vilà *et al.* 2003).

The $\delta^{13}C$ values for the Saint-Marguerite wolf are ambiguous, and we are unable to categorize this animal as either of captive or free-ranging urban origin. The $\delta^{13}C$ values of Kays and Feranec (2011) mark this animal as an "urban canid" and not wild, but attest to the statement of Darimont and Reimchen (2002) that the interpretation of isotopic signals can be challenging without relevant ecological information. Apparently, the animal had been resident for some time in an agricultural area and was feeding on domestic animals (J.-F. Dumont, Québec Ministère des Forêts, de la Faune et des Parcs, personal communication), but the origin of this wolf remains uncertain.

Although the approach presented by Kays and Feranec (2011) appears to have considerable utility in separating wild from formerly captive wolves, its value could be enhanced with a wider range of sample isotope values from animals of known diet and of wild, domestic, and urban origin. Wydeven *et al.* (1998) conclude that there is a need for better collection of data relating to dispersing wolves in the northeast, and Larivière *et al.* (2000) argue for the monitoring of wolf populations in Quebec outside wildlife reserves.

We concur, noting that we had difficulty locating the remains of the Lingwick and Saint-Marguerite wolves. Although, the collection of tissue for DNA analysis from purported wolves occurring outside their normal range now seems routine, ensuring that skeletal and hair samples from such animals are deposited in publicly maintained museum collections should likewise be a priority. The outcome of analyses of such samples may well influence future management decisions for the wolf in northeastern North America

Acknowledgements

We are grateful to Jacques Mallet, who shot the Caraquet wolf, for generously meeting our requests for information. François Chiasson, Bernard Godin, and Gérald Richardson Fish and Wildlife Branch, New Brunswick Department of Natural Resources, retrieved tissue from the Caraquet wolf for our analysis. We thank Emily Kerr, Wildlife Forensics DNA Laboratory, Trent University, for conducting genetics laboratory work and generating the raw genetic data for the Caraquet wolf. Graham Forbes and Karen Vanderwolf assisted with the necropsy and the late Dale Robinson, Tratton Run Wilderness Company, made himself available to skin the animal following examination. We thank Rick Cunjak, Heather Burke, Anne McGeachy, Christine Paton and Mireille Savoie, Stable Isotopes in Nature Laboratory, University of New Brunswick, for support with stable isotope analysis. The following people generously provided information during our efforts to locate details on purported wolves in the northeast: Jean-François Dumont, Michel Hénault, Mark McCollough, Astrid Vik Stronen, and Mario Villemure. Laurent Cloutier provided access to the Lingwick wolf skull and generously allowed us to deposit it in the Musée de la nature et des sciences, Sherbrooke, Quebec, at the conclusion of our analyses. Serge Gauthier, Musée de la nature et des sciences, Sherbrooke, was kind enough to allow hair samples to be taken from the mounted Lingwick wolf for analysis. We are very grateful to Jean-François Dumont, Québec Ministère des Forêts, de la Faune et des Parcs, for permitting access to the Sainte-Marguerite skull and collecting hair samples on our behalf from the privately held mounted animal.

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Received 11 January 2015
Accepted 28 September 2015

Notes

Three Records of Rare Blue American Bullfrogs, *Lithobates catesbeianus*, in Nova Scotia, Canada

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Gilhen, John, and Ronald W. Russell. 2015. Three records of rare blue American Bullfrogs, *Lithobates catesbeianus*, in Nova Scotia, Canada. Canadian Field-Naturalist. 129(4): 395–398.

We report three records of a rare blue American Bullfrog, *Lithobates catesbeianus*, from Nova Scotia, Canada.

Key Words: Blue bullfrog; American Bullfrog; *Lithobates catesbeianus*; dermal pigmentation; amphibian; Nova Scotia

Dermal pigmentation in amphibians is determined by chromatophores, of which the major ones are melanophores, xanthophores, and iridophores. Colouration in adult amphibians is controlled by the dermal chromatophore unit (DCU), which is formed during metamorphosis (Yasutomi and Yamada 1998). A DCU consists of xanthophores located uppermost in the dermal layer, melanophores at the bottom, and iridophores between (Bagnara *et al.* 1968). Xanthophores contain yellow pigments, melanophores express black or brown pigments derived from melanin, and iridophores contain iridescent or reflective pigments. Iridophores reflect and scatter the light that falls on them to produce a blue colour; however, the reflected light passing through the yellow xanthophores in the upper DCU appears green to the human eye. This is the basis of the usual green skin colour in adult frogs. When yellow pigment in the uppermost xanthophore layer of the DCU is sparse or absent, the frog will appear blue (axanthic). Blue colouration is highly variable and can be subtle in individual frogs.

Blue colour patterns are rare in amphibians, although they tend to be more common in Ranidae relative to other anuran families (Jablonski *et al.* 2014). A few cases of blue American Bullfrogs, *Lithobates catesbeianus*, have been documented (Berns and Uhler 1966; Bagnara *et al.* 1978; Bechtel 1995; Dodd 2013); however, location details associated with these observations are lacking. Reports of blue bullfrogs are rare in Nova Scotia. In over 50 years of amphibian observations in this province, we have recorded only three individuals, from widely separate localities on the mainland of Nova Scotia (Figure 1). There is some variation in the colour pattern of the three.

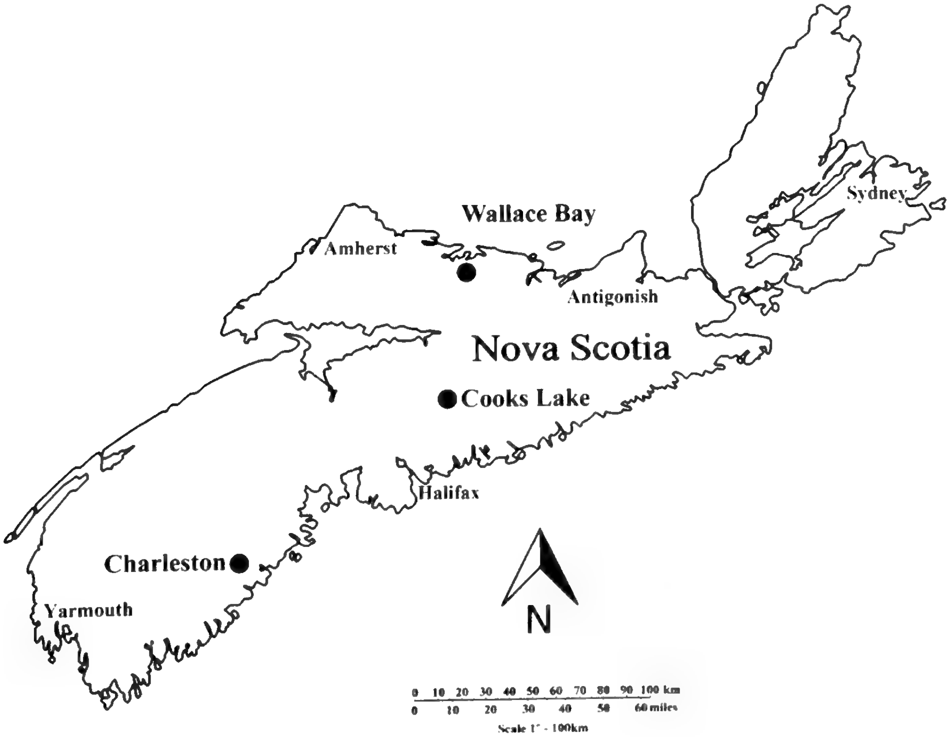

FIGURE 1. Location (black circles) of blue American Bullfrogs, *Lithobates catesbeianus*, in Nova Scotia.

The first Nova Scotia record of a blue American Bullfrog is an adult female that was photographed on the Medway River at Charleston, Queens County (44°10'00"N, 64°39'30"W) by Chris Woodworth on 26 July 1980 (Figure 2). This record, accompanied by a painting of the frog by Fred W. Scott, was published by Gilhen (1984). The back and upper sides of this bullfrog were powder blue with blackish spotting and small greenish-yellow blotches, which were larger, more frequent, and more prominent posteriorly. Both eyes had a blueish-black pupil and the irises were yellowish green with blackish freckling. Both tympana were powder blue with some yellowish-green blotches. The back of the front legs was greenish brown while the colour of the hind legs was similar to that of the trunk.

The second blue bullfrog was an adult male, photographed at the edge of Cooks Lake, Halifax County, Nova Scotia, 45°00'20"N, 63°15'00"W by Darrell Abolit, on 15 June 2007 (Figure 3). From a distance, this individual appeared powder blue on the back. Observed at close range, it had a bluish cast on an otherwise normal green colour. The bluish-black spots were darker than the rest of the back and sides. The sides of the head appeared normal in colour.

The third blue bullfrog was an adult female that was first observed in a dug pond, at Route 6, Wallace Bay area, Cumberland County, Nova Scotia, 45°48'50"N, 63°33'30"W, by Maria Duynisveld, Grace Keats, and Emma Keats, on 4 August 2014 (Figure 4 and cover). This bullfrog was blueish with large black patches. The tympana were darker blue than the rest of the body.

In natural habitat and sunlight, these frogs appear powder blue in colour to the human observer, with some brownish-black spotting, and, in the case of the Wallace Bay individual, black patches. However, in captivity, the Wallace Bay bullfrog was observed to be a metallic greyish-green colour (Figure 5). These observed colour changes could be due to changes in the quality of ambient light, from natural sun to fluorescent laboratory illumination, or to physiological colour change involving pigment translocation within the DCU. Dispersion of melanin throughout melanophores can reduce light scattering by the iridophore layer and darken the skin, causing previously light blue frogs to appear much darker. The process of physiological colour change is under hormonal control, where low concentrations of melatonin activate the Mel_{1c} receptor, resulting in movement of melanin granules toward the centre of the cell, lightening skin colour (Sugden *et al.* 2004).

FIGURE 2. First record of a blue American Bullfrog, *Lithobates catesbeianus*, an adult female, photographed at Charleston on the Medway River, Queens County, Nova Scotia, 44°10'00"N, 64°39'30"W, on 26 July 1980. Photo: Chris Woodworth.

FIGURE 3. Second record of a blue American Bullfrog, *Lithobates catesbeianus*, an adult male, photographed at the edge of Cooks Lake, Halifax County, Nova Scotia, 45°00'20"N, 63°15'00"W, on 15 June 2007. Photo: Darrell Abolit

FIGURE 4. Third record of a blue American Bullfrog, *Lithobates catesbeianus*, an adult female, captured in dug pond, Route 6, Wallace Bay area, Cumberland County, Nova Scotia, 45°48'50"N, 63°33'30"W, on 4 August 2014. Photo: Maria Duynisveld, Grace Keats, and Emma Keats.

FIGURE 5. American Bullfrog from the Wallace Bay area, Nova Scotia, photographed in captivity under artificial light. The blue parts look metallic greyish green and the black blotches look brownish black. Figure 4 shows the same bullfrog photographed in sunlight. Photo: Roger Lloyd.

Acknowledgements

The authors thank Andrew Hebda who pre-reviewed the manuscript and naturalist Interpreters, Heather McKinnon-Bradshaw, Graham Caswell, Renee McKinistry, and Liz Spence, for their professional care of live American Bullfrogs displayed in the Nature Laboratory and Netukulimk Gallery, Nova Scotia Museum. Roger Lloyd, photographer, Nova Scotia Museum, developed digital images for Figures 2, 3, and 4, and original photography for Figure 5 and the cover.

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Received 8 April 2015
Accepted 3 September 2015

Cloud Sponge, *Aphrocallistes vastus* (Porifera: Hexactinellida), Fragment Healing and Reattachment

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In May 2012, fragments of Cloud Sponge, *Aphrocallistes vastus*, that had been cut by fishing line were deposited in an array of boulders on the seabed near the parent sponge on the southwest shore of Hutt Island in Howe Sound near Vancouver, British Columbia. Open breaks in the transplanted fragments and parent sponge healed within 12 months. The fragments reattached to rock within 24 months. Previous observers of similar events reported no healing and death of damaged sponges. However, previous observations occurred during warm El Niño periods, which may be associated with higher stress leading to unsuccessful healing. In contrast, my current observations took place in cooler La Niña conditions, which may have promoted greater resilience and better healing.

Key Words: Cloud Sponge; *Aphrocallistes vastus*; tissue damage; healing; La Niña; El Niño

Introduction

Hexactinellid or glass sponges include the reef-forming dictyonine Cloud Sponge (*Aphrocallistes vastus*) and the non-reef-forming lyssasine Boot Sponge (*Rhabdocalyptus dawsoni*). Dictyonine hexactinellid sponges, including the Cloud Sponge, have been documented in British Columbia in the form of reefs (Conway *et al.* 1991) and sometimes show damage from fishing gear (Cook *et al.* 2008). These reefs are unique to British Columbia (Krautter *et al.* 2001).

Prior work during years that encompassed an El Niño climate phase (1991–1993) described slow growth rates in Boot Sponges (Leys and Lauzon 1998). Slightly faster growth of Boot Sponges was reported for 1990–1991 in Howe Sound, before the 1991–1992 El Niño phase (Marliave 1992). In addition, slow growth and extreme susceptibility to destruction by mechanical damage have been reported anecdotally for British Columbia Cloud Sponges after the 2002–2003 El Niño period (Austin 2003). Freese *et al.* (1999) found that 67% of erect sponges (including glass sponges) were damaged by trawl fishing.

The capacity for tissue healing by sponges in situ on the seabed is an important issue in fisheries conservation. Here, I expand knowledge of Cloud Sponge healing and reattachment by describing fragments cut by fishing gear and their subsequent recovery during the cooler conditions associated with the 2010–2012 La Niña events.

Methods

On 24 April 2012, a dive team and I initially observed fishing gear damage to Cloud Sponges along the southwest shore of Hutt Island (49°24.34'N, 123°22.96'W) in Howe Sound, near Vancouver, British Columbia, at a depth of 16 m (Figure 1A). We observed sponge frag-

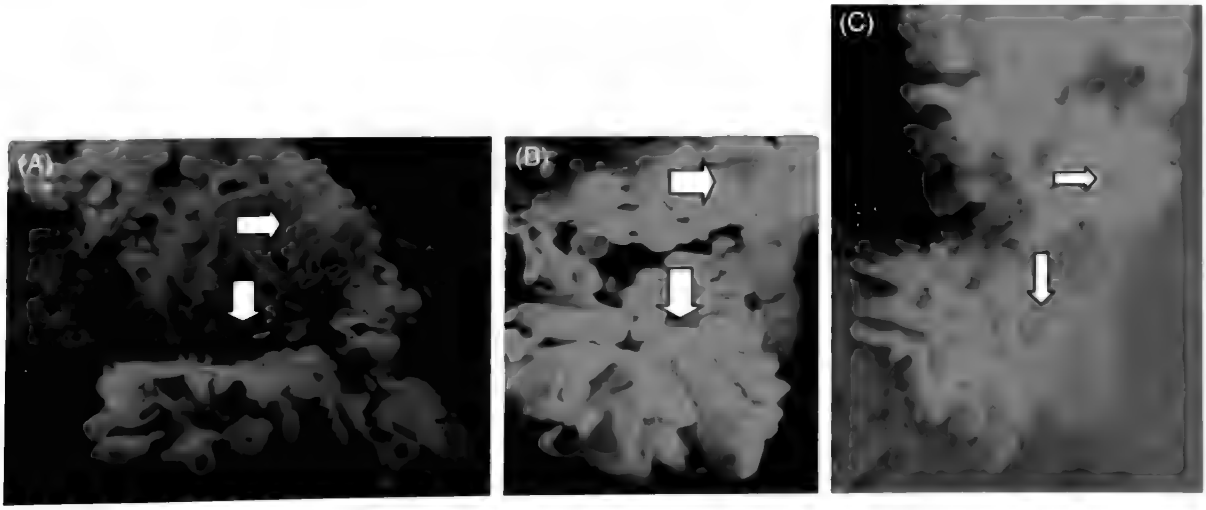

FIGURE 1. (A) Original cuts produced by fishing gear in an attached Cloud Sponge (*Aphrocallistes vastus*) in April 2012. (B) Same cuts in December 2012 with view angle shifted to the right, upslope side. Note healing of cuts. (C) In February 2015, growth is apparent. Tissue healing occurred over the first two years, then initial growth became apparent by 2015. Size of arrows indicates approximate scale. Photos: Jeff Marliave.

ments on four subsequent dives in May. On 3 May 2012, a large fragment cut from a sponge was resting against an attached Cloud Sponge below the damaged parent sponge. On 10 May, this fragment had drifted deeper to the east. On 15 May, divers transplanted the fragment to two contiguous boulders lying at right angles to each other. The fragment was seated on the north side of the southerly, downhill boulder and against the west side of the rock abutting the upper east corner of the downhill boulder. Several smaller sponge fragments from the same damaged parent sponge were tucked into a space at the corner where the two boulders met, between the rocks and the large sponge fragment. Note that the majority of sponge (about 2 m^3) removed by cutting had been swept away by currents before any of our observations. On 5 September 2012, the retrieved and placed fragments had drifted upslope from the array of rocks; thus, six small rocks were rolled into place to create a complete box around the sponge fragments at the transplant site, thereby securing them against further drift.

Photographs were taken during 20 dives conducted over three years. The extent of tissue recovery (healing of open damage, fusion of fragments to each other, and attachment to rock) was determined through examination of these photographs. No attempt was made to measure growth expressed as increase in size.

In addition to the loss of fragments, the damaged parent sponge had sustained a slice wound at its top, with the uphill portion still attached but lying against the bedrock. The outcome of this tissue damage to the intact parent sponge was also monitored with photography during inspection of the transplanted fragments.

Results

On 5 July 2012, healing of cuts and breaks and fusion of separate fragments were visible. The healing remained superficial (it did not encompass glass spicule deposition) through the winter of 2012–2013. Soft tissue covering former breaks was visible in April 2013 (Figure 2). Obvious adhesion to the rocks was observed by March 2014 (Figure 3B). Figure 3A, from 4 December 2012, shows an intact face, which had not been cut, of the largest sponge fragment, as well as a separate, protruding fragment at the rear.

By 16 February 2015, the healed, fused, and attached sponge appeared to have grown higher than the southern, downslope rock (Figure 3C). Although measurements were not taken, the growth approximated 10 cm upward and outward, which is within the range of rate of growth reported by Austin *et al.* (2007).

During the same period, the attached fragment from the slice wound on the parent sponge demonstrated comparable healing: cuts were covered with soft tissue by 5 July 2012 on both the transplanted fragment and on the attached cut pieces. Healing of the attached cuts appeared to involve spicule architecture by 4 December 2012 (Figure 1B). However, it was not until 2014 that new attachments to rock were observed at both the upper attached cut piece and in the transplanted fragment (Figure 1C and Figure 3B, C).

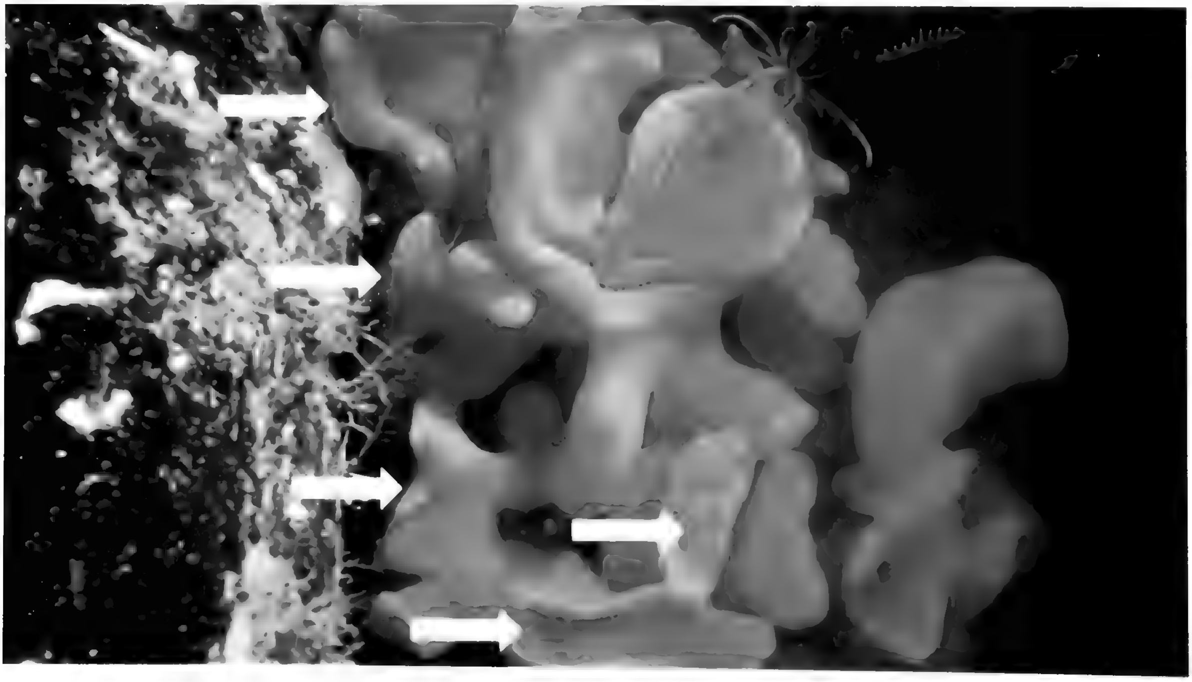

FIGURE 2. Early healing of cuts and breaks in Cloud Sponge (*Aphrocallistes vastus*), indicated by arrows, viewed from above, adjacent to the north side of south rock in April 2013. Sponge has yet to attach to rock. Photo: Jeff Marliave.

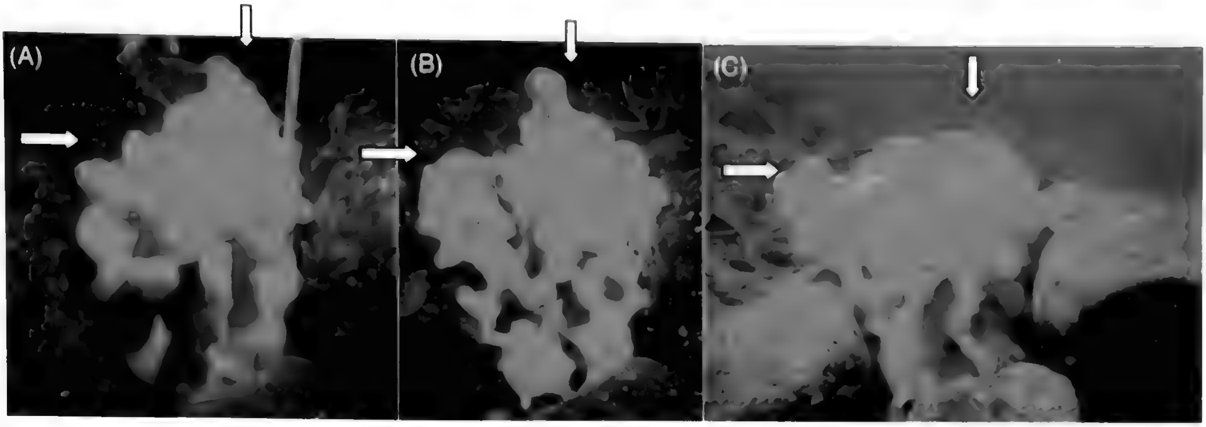

FIGURE 3. (A) In December 2012, view from west shows Cloud Sponge (*Aphrocallistes vastus*) fragment and south rock at same height. Note gloved fingers (not sponges) and ruler at top of photo. In September 2012, smaller rocks had been placed to the west and north (bottom and left) to hold fragments in place. Sponge had yet to attach to rock. (B) In March 2014, the same view shows healed sponge attached to rocks. The rear portion protruding upward at the east side was previously a separate pair of smaller fragments that fused together during 2012 and attached to rock in 2013. Note that the main body of the sponge is not appreciably higher than at the outset of the observations, as evidenced by the relative position of the south rock at the right. (C) In February 2015, the sponge had grown above the rocks and was spreading over them. The photo angle in C is more horizontal than in A and B; thus, the elevated eastern portion indicated by the upper arrow is behind the forward, western mass of sponge. Photos: Jeff Marliave.

Discussion

The current observations of tissue recovery and fusion occurred during a cooling La Niña climate phase. None of the earlier literature on glass sponges has contextualized observations in terms of the El Niño/Southern Oscillation phase of climate occurring at the time.

Prior accounts emphasize frailty and slow growth of glass sponges (Austin 2003), but these observations were mostly conducted during warm conditions associated with the 2002–2003 El Niño. The growth observations of Austin *et al.* (2007: Figures 1 and 3) provide dated measures that span a sequence from El Niño to La Niña climate phases, with slower growth occurring during the 2002–2003 El Niño, followed by faster growth during the 2005–2006 La Niña. In the absence of online index values (Climate Prediction Center Internet Team 2015), the results were interpreted as faster growth related to larger size.

However, our recent observations suggest that healing capacity increases during cooler La Niña phases, although the extent to which growth rates may vary according to such climate phases remains to be determined. To further support this hypothesis, it will be necessary to document glass sponge healing and growth during subsequent El Niño and La Niña events, and to record temperatures continuously at monitoring sites.

Acknowledgements

I am grateful to the following divers for assistance: Donna Gibbs, Alejandro Frid, Jonathan Wong, Sean Oswald, Laurel Johnstone, and Justin Lisaingo. Alejandro Frid provided editorial comments during manuscript preparation.

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Received 6 March 2015
Accepted 24 September 2015

Diet and Feeding Behaviour of Snapping Turtles (*Chelydra serpentina*) and Midland Painted Turtles (*Chrysemys picta marginata*) in Algonquin Provincial Park, Ontario

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Moldowan, Patrick D., Matthew G. Keevil, Peter B. Mills, Ronald J. Brooks, and Jacqueline D. Litzgus. 2015. Diet and feeding behaviour of Snapping Turtles (*Chelydra serpentina*) and Midland Painted Turtles (*Chrysemys picta marginata*) in Algonquin Provincial Park, Ontario. Canadian Field-Naturalist 129(4): 403–408.

We compare diet and feeding behaviour of Snapping Turtles (*Chelydra serpentina*) and Midland Painted Turtles (*Chrysemys picta marginata*) in Algonquin Provincial Park, Ontario, Canada. We observed young *Chelydra* and *Chrysemys* turtles feeding on insect and amphibian larvae in ephemeral ponds, adult *Chrysemys* terrestrially foraging on odonate larvae, and adult *Chelydra* consuming aquatic vegetation and seeds. These and other observations highlight the importance of seasonally available habitat and food for juvenile turtles. We also discuss the evidence for, and importance of, turtles as seed-dispersal agents for aquatic vegetation. Illustrative video recordings accompany our dietary observations.

Key Words: Amphibian larvae; Snapping Turtle; *Chelydra serpentina*; Midland Painted Turtle; *Chrysemys picta marginata*; diet; ephemeral pond; odonate; seed dispersal

Introduction

Snapping Turtles (*Chelydra serpentina*) and Painted Turtles (*Chrysemys picta*) are omnivorous and known to consume a wide variety of invertebrate, vertebrate, algae, and aquatic vascular plant species across their broad geographic ranges (Ernst and Lovich 2009). A long-term study on the life history and ecology of Snapping Turtles and Midland Painted Turtles (*C. p. marginata*) based out of the Wildlife Research Station in Algonquin Provincial Park, Ontario, has been ongoing since 1972. Here, we report observations of dietary and feeding behaviour collected during field research, principally between 2009 and 2014.

Methods

Data were collected using standard field methods, including haphazard mark–recapture surveys, nest site surveys, and radio telemetry, consistent with the long-term study (see Obbard and Brooks 1981 and Rollinson and Brooks 2007 for further details). Turtles were captured from canoe using a landing net, by baited hoop trap, and by hand and transported to a field laboratory at the Wildlife Research Station for measuring and marking. *Chelydra* were measuring using tree calipers (to the nearest 0.05 cm) and *Chrysemys* were measured with Vernier or digital calipers (to the nearest 0.01 cm). Both species were weighed using an appropriately sized spring scale (Pesola AG, Baar, Switzerland). Juvenile turtles were marked with notches in the marginal scutes (Cagle 1939). Adults were notched and also received an aluminum tag bearing an alphanumeric identification code that was affixed to the posterior marginal scutes (Loncke and Obbard 1977). Turtles less than 1 year of age were individually marked with nail polish on the plastral scutes for short-term identification. Adult *Chrysemys* were marked annually by painting a unique identification code on the carapace so that individuals could be identified from afar.

Observations and Discussion

Juvenile Diet and Feeding Behaviour

During spring and early summer 2011, frequent rains resulted in networks of ephemeral pools along low-lying areas of an old railway embankment at one of our main study sites, Wolf Howl Pond (45°34'N, 78°41'W). Parts of the embankment are the primary nesting areas for turtles in adjacent water bodies (Schwarzkopf and Brooks 1985; Rollinson and Brooks 2007). From 19 May to 24 June 2011, 33 juvenile *Chelydra* and 19 juvenile *Chrysemys* were found occupying these pools during daily checks. All were less than 1 year of age (2010 hatch year based on size and growth-ring counts): for *Chelydra*, straight midline carapace length = 2.90 ± 0.11 cm (mean ± SD), midline plastron length = 2.20 ± 0.10 cm, mass = 8.30 ± 0.96 g; for *Chrysemys*, straight midline carapace length = 2.76 ± 0.22 cm, midline plastron length = 2.62 ± 0.18 cm, mass = 4.82 ± 0.98 g.

Young turtles were observed foraging, swimming, and hiding among detritus in the shallow pools, which were 2–6 cm deep. Juvenile turtles were observed feeding on the abundant mosquito (Diptera: Culicidae) larvae present in these pools, and the two species used different behaviours to capture prey. Juvenile *Chelydra* remained motionless in ambush or exhibited a slow, stalking movement toward mosquito larvae with negligible water disturbance (see Video 1 under Supplementary Material; see also Vogt 1981 citing Bramble 1975). Prey were captured using a rapid strike and ram-feeding mechanism (Lauder and Prendergast 1992). In contrast, juvenile *Chrysemys* cued to movement of mosquito larvae and approached the prey directly. The mosquito larvae reacted by attempting to move away, and a chase would ensue (Video 2, Supplementary Material). Exploratory striking, prey disturbance, and chasing characterized the feeding strategy of *Chrysemys*, as also observed by Sexton (1959). The ambush strategy of juvenile *Chelydra* appeared to be more successful than the direct approach of juvenile *Chrysemys*, although we did not quantify putative differences in capture success. The seasonally abundant prey source and high-quality foraging opportunities provided by ephemeral pools may be important for the early growth of *Chelydra* and *Chrysemys* (Cosentino *et al*. 2010). Others report the use of seasonally flooded pools by *Chelydra* and *Chrysemys* for foraging and thermoregulation (DeGraaf and Rudis 1983; Kenney and Burne 2000; Calhoun and deMaynadier 2008; Ernst and Lovich 2009) and overwintering (MGK and PDM, personal observations of juvenile *Chelydra* in Algonquin Park).

On 27 August 2011, a yearling *Chelydra* was observed in shallow water along the shoreline of Wolf Howl Pond. The young turtle had grasped the left hind limb of a partly metamorphosed Mink Frog (*Lithobates septentrionalis*) in its jaws and had partly eviscerated the frog during prey handling (Figure 1). Although only in its first growing season, this *Chelydra* demonstrated the aggressive feeding response typically associated with adults (Ernst and Lovich 2009) when it attempted to capture prey almost as large as itself.

Heavy and regular rainfall in summer 2014 resulted in the formation of ephemeral pools along Ramona Lake Road (45°29'N, 78°45'W), which leads to a waste transfer station and aggregate pit in Algonquin Park. In addition, rainwater pooled in a tarpaulin that was installed to inhibit the growth of Common Reed (*Phragmites australis* (Cavanilles) Trinius ex Steudel) and in low-lying areas with a silty substrate ("settled fine dust" left behind after heavy machine work). Young *Chrysemys* were observed in the pools throughout August. In one pool, measuring 10–12 m in diameter and 5 cm deep, Gray Treefrog (*Hyla versicolor*) larvae were observed. Wandering Glider dragonflies (*Pantala flavescens* (Fabricius) [Odonata: Libellulidae]) were also observed courting and depositing eggs at the pools. *Hyla* larvae were extremely abundant in one pool on 9 August 2014, and three young *Chrysemys* (fall 2013 hatchlings based on size and plastron growth-ring count) were observed preying on them. Visual inspection showed wide spacing between the natal scute (present at hatching) and first growth ring on the plastron of all three juvenile *Chrysemys*, suggesting rapid growth in their first active season (2014). A combina-

FIGURE 1. Yearling Snapping Turtle (*Chelydra serpentina*), 2010 hatch year, restraining a partly metamorphosed Mink Frog (*Lithobates septentrionalis*) by the left hind limb, 27 August 2011, Algonquin Provincial Park, Ontario, Canada. Photo: M. G. Keevil.

tion of shallow water, extreme exposure to sunlight, and (in the case of one series of pools) a dark underlying tarpaulin, likely resulted in warm water temperatures in these ephemeral pools. Such warm water conditions and access to an abundant prey source would account for rapid first-year growth of these juvenile *Chrysemys* relative to growth in other Algonquin populations (MGK, unpublished data). A juvenile *Chelydra* was also observed feeding on *Hyla* larvae in a flooded ditch adjacent to Highway 60 near Found Lake (45°33'N, 78°38'W) for at least 2 weeks during summer 2015.

Amphibian larvae exhibit a range of morphological and behaviourial responses to predation risk (Relyea 2001, 2004). *Hyla* larvae display conspicuous red colouration of the caudal fin when developing in the presence of (odonate) predators (McCollum and Leimberger 1997). However, despite exposure to turtle predators, *Hyla* larvae found in the Ramona Lake Road pools and the roadside ditch did not display red colouration. Odonates and predacious diving beetles (Coleoptera: Dytiscidae) chew and shred larval anurans and thus broadcast alarm cues into the environment, whereas, in most cases, turtles swallow anuran larvae whole. Compared with predatory insects, turtles are likely less frequent and less predictable predators of anuran larvae. Perhaps the different feeding strategies and predation pressure exerted by aquatic insects and turtles would elicit different magnitudes of plastic (morphological or behavioural) response from anuran larvae. Future work should consider turtles as a predator in anuran larvae plasticity experiments.

Consumption of Aquatic Vegetation and Seed Dispersal

Aquatic vegetation makes up a large portion of the diet of adult *Chelydra* (Alexander 1943; Lagler 1943; Hammer 1969; Punzo 1975; Ernst and Lovich 2009) and *Chrysemys* (Raney and Lachner 1942; MacCulloch and Secoy 1983; Lindeman 1996; Rowe and Parsons 2000; Ernst and Lovich 2009; Padgett *et al.* 2010). In addition, watershields (*Brasenia* spp.) and water-lilies (*Nuphar* spp. and *Nymphaea* spp.) serve as food and cover for *Chelydra* (Obbard and Brooks 1981) and *Chrysemys* (Sexton 1959). Throughout the active season for turtles in Algonquin Park (May–August), *Chelydra* have been observed feeding on Watershield (*Brasenia schreberi* J. F. Gmelin).

On 29 May 2010, an adult male *Chelydra* (straight midline carapace length = 31.7 cm; mass = 8.9 kg) was video-recorded feeding on Watershield in Wolf Howl Pond (Video 3, Supplementary Material). *Chelydra* appear to locate Watershield visually and approach clusters of leaves at the water's surface. Watershield leaves are consumed one at a time by rapid forward extension of the neck and depression of the hyoid, akin to the ram-feeding/suction mechanism employed when feeding on animal prey (Lauder and Prendergast 1992; Summers *et al.* 1998). *Chelydra* may use their forelimbs and claws to sever the long trailing stem of Watershield, just as when handling oversized prey (Punzo 1975). They may also use their forelimbs to drag a Watershield leaf under water before striking and consuming it. Examination of the gut of a road-killed adult male *Chelydra* (straight midline carapace length = 34.0 cm, mass = 9.0 kg), found on 21 August 1992 on Highway 60 in Algonquin Park, revealed very densely packed Watershield, essentially filling the entire alimentary tract from stomach to cloaca. This Watershield showed little sign of digestion, and even leaves near the cloaca appeared freshly eaten. Although the mucilage coating on Watershield deters insect predators (Thompson *et al.* 2014), it seemingly does not discourage consumption by *Chelydra*.

We have observed consumption of flowers and seedpods of Variegated Pond-lily (*Nuphar variegata* Engelmann ex Durand) by *Chelydra* directly, and indirectly in feces. The seeds of this plant are also abundant in feces of *Chrysemys* in Algonquin Park. *Chelydra* (Kimmins and Moll 2010) and *Chrysemys* (Raney and Lachner 1942; Padgett *et al.* 2010) appear to be important seed dispersers for aquatic plants. A literature review (Traveset 1998) and subsequent publications (e.g., Varela and Bucher 2002; Strong and Fragoso 2006; Griffiths *et al.* 2011; Blake *et al.* 2012) suggest that turtles (and other seed-eating reptiles) may help, or at least not hinder, the germination rates of seeds that pass through their digestive tracts. Seed dispersal has been described for numerous chelonian species: *Trachemys scripta elegans* (Kimmons and Moll 2010), *Terrapene carolina* (Braun and Brooks 1987; Liu *et al.* 2004), *Emys orbicularis* (Calvino-Cancela *et al.* 2007), *Chelodina longicollis* (Burgin and Renshaw 2008), *Elseya* spp. (Kennett and Russell-Smith 1993; Freeman 2010), *Gopherus polyphemus* (Carlson *et al.* 2003), *Chelonoidis chilensis* (Varela and Bucher 2002), *Geochelone nigra* (Blake *et al.* 2012), *G. carbonaria* and *G. denticulata* (Strong and Fragoso 2006; Guzmán and Stevenson 2008; Jerozolimski *et al.* 2009), *Gopherus agassizii* (Woodbury and Hardy 1948), *Testudo graeca* (Cobo and Andreu 1988), *Aldabrachelys gigantea* (Wickens 1979; Griffiths *et al.* 2011), and *Rhinoclemmys* spp. (Moll and Jansen 1995). Seed dispersal is also suspected in *Podocnemis expansa* (Kubitzk and Ziburski 1994), *Sternotherus odoratus* (Ford and Moll 2004), *Macroclemys temminckii* (Sloan *et al.* 1996), and numerous members of Old World Geoemydidae (Carlott 1998), among other species (Moll and Moll 2004). Given the relatively large number of species known to consume seeds, chelonians are of great potential importance as seed dispersers and contributors to aquatic and terrestrial ecosystem function.

Additional Dietary Observations of Adult Chrysemys and Chelydra

Other observations of *Chrysemys* and *Chelydra* related to diet and feeding have been recorded during the long-term research on these species in Algonquin Park. Most observations of feeding have been of the consumption of plant material during mid-to-late summer when aquatic vegetation is abundant. However, turtles appear to be more carnivorous in spring when less vegetation is available and animal prey is more exposed (e.g., breeding and laying amphibians). On several occasions, adult *Chelydra* were observed pursuing and eating American Bullfrogs (*Lithobates catesbeianus*); these events typically involved a short, rapid chase by the turtle after which the frog was quickly dispatched. On one occasion in June, young Common Grackles (*Quiscalus quiscula*) prematurely exited their nest, which was in a hollow tree over a pond, and fell to the water surface where a large male *Chelydra* captured and ate them. Adult *Chelydra* are easily trained to take fresh fish from researchers in canoes, and they readily consume up to 10% of their body mass at a feeding (Brown and Brooks 1991).

On 7 May 2011, an adult female *Chrysemys* (straight midline carapace length = 14.79 cm, mass = 465 g) was observed feeding on a Spotted Salamander (*Ambystoma maculatum*) egg mass in Wolf Howl Pond. The turtle was captured and fragments of the gelatinous egg mass were observed in her mouth. On 22 May 2011, an adult female *Chrysemys* was seen climbing onto *Sphagnum* bog mats to catch emergent dragonfly larvae that were preparing to metamorphose (Video 4, Supplementary Material). The turtle appeared to search actively for terrestrial prey and to identify visually motionless dragonfly larvae. This turtle plucked dragonfly larvae from low-lying stems of bog vegetation and carried her prey back to water before feeding. Freshwater turtles have a soft, flattened eye lens that permits emmetropic (normal-sighted) vision and comparable focus in air and water (Walls 1942; Dudziak 1955; Granda and Dvorak 1977; Northmore and Granda 1991; Kröger and Katzir 2008), perhaps allowing efficient foraging in both media. *Chrysemys picta*, among other aquatic turtle species, can experience difficulty swallowing prey out of water (Bramble 1973; Bramble and Wake 1985), and turtles may return to the water to feed because aquatic suction enhances feeding efficiency (Stayton 2011) or because being in water may reduce exposure to predators. Dragonfly prey species were not identified, although 15 species of 10 genera and four families with spring emergence dates have been identified at Wolf Howl Pond (PBM, unpublished data). Sexton (1959) also reported *Chrysemys* foraging on mats of aquatic vegetation and pursuing odonate larvae. As noted above for mosquito and anuran larvae, the seasonally available dragonfly larvae, among other aquatic insects (Rowe and Parsons 2000), may be an important food source for turtles.

Acknowledgements

We thank countless past contributors to the long-term turtle study in Algonquin Park. Financial support for the study has largely been through Natural Sciences and Engineering Research Council grants to RJB and JDL. We also thank the Algonquin Wildlife Research Station, R. Eckenswiller, J. Hoare, B. Steinberg, S. Dobbyn, and Ontario Parks for logistical, in-kind and financial support; A. M. Bennett for use of video footage and comments that improved the manuscript; and J. R. Riley for field assistance and retrieving an elusive reference. Research was conducted under approved Laurentian University Animal Care Protocols (AUP 2008-12-02 and 2013-03-01) and Ontario Parks field research permits.

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Received 20 May 2015
Accepted 26 October 2015

SUPPLEMENTARY MATERIAL:

VIDEO 1. Young Snapping Turtle (*Chelydra serpentina*) preying on mosquito larvae (Diptera: Culicidae) in an ephemeral pool in Algonquin Provincial Park, Ontario, Canada. Note the stalking and ambush behaviour, in contrast with the feeding strategy of a young Midland Painted Turtle (*Chrysemys picta marginata*) in Video 2.

https://www.youtube.com/watch?v=2Ea5xZIH5n8

VIDEO 2. Young Midland Painted Turtle (*Chrysemys picta marginata*) preying on mosquito larvae (Diptera: Culicidae) in an ephemeral pool in Algonquin Provincial Park, Ontario, Canada. Note the active chase feeding behaviour, in contrast with the feeding strategy of young Snapping Turtle (*Chelydra serpentina*) in Video 1.

https://www.youtube.com/watch?v=A0poVfMIEeY

VIDEOS 3A and 3B. Adult male Snapping Turtle (*Chelydra serpentina*) feeding on Watershield (*Brasenia schreberi* J. F. Gmelin) at Wolf Howl Pond, Algonquin Provincial Park, Ontario, Canada.

https://www.youtube.com/watch?v=G4up-fkXbss&feature=youtu.be
https://www.youtube.com/watch?v=WcNNiHO4tas

VIDEOS 4A and 4B. Adult female Midland Painted Turtle (*Chrysemys picta marginata*) preying on emergent dragonfly larvae (Odonata: Anisoptera) preparing for metamorphosis at Wolf Howl Pond East, Algonquin Provincial Park, Ontario, Canada. Recorded by A. M. Bennett.

https://www.youtube.com/watch?v=Z7LNdafj1HQ&feature=youtu.be
https://www.youtube.com/watch?v=ryZ6JSfXbno&feature=youtu.be

Book Reviews

Book Review Editor's Note: We are continuing to use the current currency codes. Thus Canadian dollars are CAD, U.S. dollars are USD, Euros are EUR, China Yuan Remimbi are CNY, Australian dollars are AUD and so on.

ZOOLOGY

A Field Guide to Common Fishes of the Pacific Northwest

By Andy Lamb, Bernard Hanby, and Phil Edgell. 2015. Harbour Publishing, Box 219, Madeira Park, BC, Canada, V0N 2H0. 7.95 CAD, Plasticised pamphlet.

Many years ago I went on a trip that included my first whale watching excursion. I did not want to take a mammal book, but I needed something to help with cetaceans. I took a kitchen recipe card and drew diagrams and sketches of the whales and dolphins I had a chance of seeing. This fit in my shirt pocket and worked out well. I still have this card. A few years later I converted the pencil sketches to ink drawings and plasticised the card with shipping tape. Many years later I discovered that people had begun publishing commercially plasticised cards.

The latest addition to these cards is a guide to Pacific fish. Most of us are not licensed scuba divers with expensive underwater cameras, so are not likely to photograph deep sea fish. I have a small point-and-shoot that is waterproof and I have taken a number of fish photos by hanging off the dock or boat and lowering my camera in to the water.

So I was surprised by how many of the fish, shown in this pamphlet, that I have seen. Some I have watched from a ship's side as they swam around the bow. Searching rock pools (always fun) has added more. Others I have seen as the catch in indigenous fishermen's boats. I have also visited some local fish markets. Of course, I have eaten several species.

The 105 photos, by Hanby, are simply wonderful. How he got a Wolf-eel to pose not once, but twice could only be accomplished with immense patience. Incidentally the Wolf-eel has been described as having a face only a mother could love or fierce looking. I prefer these authors's more kindly description as "resembling a Muppet puppet." Other fish, like the Tiger Rockfish, would be more universally called beautiful. Each photo carries a short note on the fish's biology. The authors use five symbols to denote fish that can be caught by anglers, seen by divers, are commercially harvest, are good to eat, and can be found in pools, off docks, and boats. This last symbol is important for visitors as they indicate that over 50 per cent of the species can be seen by a land-bound naturalist.

This is another delightful, lightweight guide from Harbour Publishing (Harbour has recently published *A Field Guide to Seaweeds of the Pacific Northwest*). As I expect to be on the west coast next February, I will be using this pamphlet in the field soon. It is a good purchase for any naturalist and fisherman and another ideal stocking stuffer.

Roy John

2193 Emard Crescent, Ottawa, ON, Canada, K1J 6K5

BOTANY

A Field Guide to Seaweeds of the Pacific Northwest

By Bridgette Clarkson. 2015. Harbour Publishing, Box 219, Madeira Park, BC, Canada, V0N 2H0. 7.95 CAD, Plasticised pamphlet.

Seaweeds can be a bit frustrating. On a trip I normally pack a bird and a flower guide, so I do not have information on seaweeds with me. Back home I look at notes and photos to try and identify what I have seen. This not always ideal. A year ago I got a plasticised pamphlet on butterflies and it sits in my glove box (not in my bookcase in the house) and it has been so useful. I am now a fan of such publications, so welcome this lightweight guide.

The coast of British Columbia and Alaska is one of the best places to see seaweeds (and other rock pool life). This pamphlet shows a selected 48 types from the 640 possible species. Some of the types are identified to genus only, as going to the species level is beyond this publications scope. The author takes two panels to introduce basic seaweed biology. This is worthwhile as most of us landlubbers only get to the coast at infrequent intervals. She then splits her photo identification section into four: brown, red, and green seaweeds, and seagrasses. So once you decide on the colour you can pick through the handful of pictures to get the best match. Almost all the species range from Alaska south to Mexico or California.

I picked my way through and recognised about half the species depicted. Clearly I need to work on my red seaweed list. The easiest to pick out are the kelp species, particularly the iconic Bull Kelp (*Nereocystis luetkeana*). Most people will be familiar with Rockweed or Bladderwrack (*Fucus* species). Indeed my notes (from 1963) show this is the first genus I identified. Another easy pick is the bright green Sea Lettuce (*Ulva linza*), a species with a very wide distribution. The author uses the green seaweeds to raise the issues of harvesting. As she says, seaweeds are delicious, but we need a conservation ethic when harvesting. My personal favourite is Miyeok or Wakame (*Undaria pinnatifida*), a lovely crunchy dish from Korea.

This is a delightful guide and, as it weighs only a few grams and takes up no space, I will not be leaving it behind. I expect to be on the west coast next February and I look forward to using this pamphlet in the field. It is a good purchase for any naturalist and an ideal stocking stuffer. (Harbour has also just published a similar pamphlet – *A Field Guide to Common Fishes of the Pacific Northwest*.)

ROY JOHN

2193 Emard Crescent, Ottawa, ON, Canada, K1J 6K5

OTHER

The Carbon Bubble

By Jeff Rubin. 2015. Random House Canada, 320 Front Street West, Suite 1400, Toronto, ON, Canada, M5V 3B6. 246 pages, 32.00 CAD, Cloth.

A fascinating easy-to-read analysis of the science, economics, and politics of Canadian oil sands development that considers local, national, and global issues. Rubin explains complex interconnected issues of climate change and oil sands development in a way that is accessible without insulting your intelligence. Traditional thinking assumes development must always be linked with increased carbon emissions. Consequently anything that would limit carbon emissions (such as a cap or tax on emissions or, in the case of Canada, labeling oil sands as an excessive emitter of carbon) is considered to have negative consequences for economic growth and is thus labeled as a "bad" for Canada's Gross Domestic Product (GDP)!

Rubin shows however that increasingly there are examples of increased economic growth with technological strategies that increase GDP while simultaneously reducing carbon emissions, hence "green growth". There is consensus the world should not let the global average temperature increase more than two degrees Celsius; thus there is a fixed carbon budget that is defined by the two degree threshold. More progressive thinking rejects an economic future based on high carbon emissions such as oil sands development. Rubin's documentation of the now largely bankrupt coal industry is a clear wake-up call for the most carbon intensive of all oil production, oil sands, clearly the industry next in line when it comes to regulating the big emitters.

As most of us already know, Canada is increasingly occupying a unique position globally – a country that ignores global concern and actions on Climate Change and which banks economic development on conventional carbon energy sources. Rubin's book is a much needed wake up call.

BRENT TEGLER

Médecins Sans Frontières, Myanmar

Handbook of Road Ecology

Edited by Rodney van der Ree, Daniel J. Smith, and Clara Grilo. 2015. Wiley Blackwell, 9600 Garsington Road, Oxford, UK, OX4 2DQ. 522 pages, 176 CAD, Cloth.

What do roads have to do with ecology? With over 60 million kilometres of roads on Earth, roads have destroyed and fragmented ecosystems around the world. The science of road ecology seeks to better understand the threats that roads pose and provide solutions to those threats. This new book, *Handbook of Road Ecology*, is a multi-authored volume that summarizes current research in a variety of areas of road ecology.

The book is composed of 62 chapters authored by over 100 experts in road ecology: academics, practitioners, and transportation agency personnel from 25 different countries. To help ensure a broad perspective, most chapters were written by more than one author, generally from different countries. Each chapter follows a standard format with a summary, introduction, lessons, conclusions, further reading, and references. The lessons are the core of each chapter. The editors required the authors to provide a numbered list of "insights or principles" on their topic. The goal is that readers can quickly find relevant topics within a chapter. Overall, this approach is effective as each chapter is a standalone document. Authors were also asked to keep each chapter to 3,000 words or less. The book is well illustrated with many photos (most of them in colour), maps, and graphs.

The chapters span a wide range of topics including road planning and design, impacts on various groups of organisms, monitoring strategies, mitigation approaches, and case studies. While the main focus is on roads, a few chapters address other linear infrastructure such as railways and utility corridors. Individual chapters examine the effects of roads on invertebrates, amphibians, reptiles, fish, birds, bats, carnivores, and small mammals, with case studies on crabs, jaguars, tigers, elephants, and canopy bridges for primates. Additional chapters focus on particular landscapes such as arid lands or tropical ecosystems. Other chapters profile particular areas including the Amazon, southern India, the Serengeti, South Africa, and China.

One minor annoyance is that the table of contents does not group chapters into major sections. A few key section headings would make it easier to find broad topics. Individual chapters provide a good overview of topics but they are not exhaustive. Additional references could have been provided in many chapters to allow readers to dive into the topics in greater detail. For example, in the chapter on reptiles, the authors cite a couple of papers on drivers intentionally running over reptiles but don't cite a later, key paper on the topic. This can make it difficult for readers to find recent papers on a topic. Overall, though, this is an excellent summary of a fast-growing body of knowledge in a critical area of ecology.

DAVID SEBURN

Seburn Ecological Services, 2710 Clarenda Street, Ottawa, ON, Canada, K2B 7S5

The New Labrador Papers of Captain George Cartwright

Edited by Marianne P. Stopp. 2008. McGill–Queen's University Press, 1010 Sherbrooke West, Suite 1720, Montreal, QC, Canada, H3A 2R7. 256 pages, 29.95 CAD, Paper.

Captain George Cartwright was a trader on the Labrador coast from 1770 to 1779 and 1783 to 1786, who, in 1792, published a three volume journal of his Labrador experiences. Despite, or perhaps because of "the simplicity of plain language and downright truth", his account was admired both by Robert Southey and Samuel Taylor Coleridge for its "odd" and "strange simplicity". Stopp's book is an admirable rescue of further, previously unpublished, Labrador documents of Cartwright's. Her five background chapters place George Cartwright in perspective and cover his Labrador writings, human settlement of Labrador, an account of his life, a description of the new George Cartwright papers, and the historical relevance of those papers. The bulk of the book, pages 88–191, provides a pot-pourri of additions to Cartwright's 1792 journal. Many of the items are evidence of Cartwright's interest in natural history and in the skills necessary to survive in the challenging Labrador environment. The book includes seventeen letters, eight of them written by George in Labrador in 1771.

Are there disappointments? Yes, two. Though Stopp's introduction and annotations are excellent, parts of the Cartwright material may not be of interest to the general reader. The additions to Cartwright's earlier publications are informative and confirm his interest in natural history but, through no fault of Stopp's, are presented in Cartwright's own haphazard sequence, not always a pleasure to read. "Simplicity of plain language and downright truth" does not necessarily make for easy or interesting reading.

Since the word "curlew" appears only once in the additions to Cartwright, Stopp might be excused for what was my second disappointment: not mentioning Cartwright's main claim to fame, the high esteem in which he is regarded by modern ornithologists. I believe most of Stopp's readers would have appreciated the addition of a few facts from Montevecchi and Tuck's definitive *Newfoundland Birds* (1987), which rated George Cartwright as "a curious naturalist, a natural historian par excellence", and as the first person to warn of the impending extinction of the Great Auk, then breeding in numbers on Funk Island. Cartwright also documented that the seasonal molts of ptarmigan resulted from feather molts.

Gollop, Barry, and Iversen's book, *The Eskimo Curlew, a Vanishing Species?* (Saskatchewan Natural History Society special publication #17, 1986), confirms that George Cartwright's 500 specimens, collected mainly for food, provide "the best calendar of comings and goings ever compiled. … Eskimo Curlews were one of the delicacies they sought although they did not always have far to go …". Gollop *et al.*'s nine pages listed the 102 sightings recorded by George Cartwright during the migration of the then common Eskimo Curlew. The birds arrived as early as 28 July (1777) and departed as late as 24 October (1772). The Eskimo Curlew is thus the second bird species from Labrador, known mainly from Cartwright sightings, that is now believed to be extinct, a sad ending of great biological significance that should have been worthy of at least brief mention.

My quibbles are those of an avid ornithologist. Stopp's book is an important historiographic document; it has provided a context for Cartwright's material. Her book will be of interest to anyone with a strong interest in the history of Labrador, and is a worthy addition to college and university libraries, especially those which focus on Newfoundland Labrador.

C. STUART HOUSTON

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned
Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros

ZOOLOGY

The Bees in Your Backyard: A Guide to North America's Bees. By Joseph Wilson, and Olivia Messinger Carril. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 288 pages, 29.95 USD, Paper.

Better Birding: Tips, Tools, and Concepts for the Field. By George Armistead, and Brian Sullivan. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 360 pages, 29.95 USD, Paper.

Birds of Botswana. By Peter Hancock, and Ingrid Weiersbye. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 400 pages, 29.95 USD, Paper.

Britain's Mammals: A Field Guide to the Mammals of Britain and Ireland. By Dominic Couzens, Andy Swash, Robert Still, and Jon Dunn. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 320 pages, 29.95 USD, Paper.

Offshore Sealife ID Guide: East Coast. By Steve N.G. Howell, and Brian Sullivan. 2015. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 64 pages, 14.95 USD, Paper.

BOTANY

Lady's Slipper Orchids of India. By H.J. Chowdhery, Bishen Singh, and Mahendra Pal Singh. 2015. 23 Connaught Place, Dehra Dun, UAA, India, 248001. 164 Pages, 80.00 USD, Cloth.

News and Comment

The Canadian Herpetologist (TCH) 5(1), Spring 2015

The Canadian Herpetologist (TCH) is a publication produced twice each year by the Canadian Association of Herpetologists and the Canadian Amphibian and Reptile Conservation Network.

CONTENTS: Executive Members of Societies — Instructions for Authors — Editorial Notes — Meetings — Feature Article: The Distribution of Northern Map Turtles (*Graptemys geographica*) on the Grand River and in Wetlands Associated with Lake Ontario *by D. Scallen* — Field Notes: 'Twas the Night Before Field Season *by P. Moldowan*; The Wandering Salamander *by K. Ovaska* — Thesis Abstracts in Canadian Herpetology: **Juneau, V.** M.Sc. 2014. University of Ottawa, Ottawa, ON. (Supervisor: G. Blouin-Demers). Chronically elevated corticosterone levels, via cocoa butter injections of corticosterone, do not affect stress response, immune function, and body condition in free-living Painted Turtles (*Chrysemys picta*). **Marchand, K.A.** B.Sc. 2015. Laurentian University, Sudbury, ON. (Supervisors: J.D. Litzgus and G.N. Hughes). Geographic variation in somatic growth rate of Wood Turtles (*Glyptemys insculpta*). — **Myschowoda, K.R.** B.Sc. 2015. Lakehead University, Thunder Bay, ON. (Supervisor: S.J. Hecnar). Caudal autotomy as a function of potential predators of the Common Five-lined Skink (*Plestiodon fasciatus*) at Point Pelee National Park. — **Szabo, A.** B.Sc. 2014. University of Ottawa, Ottawa, ON. (Supervisor: G. Blouin-Demers). Factors influencing parasite load in male Ornate Tree Lizards (*Urosaurus ornatus*): throat colour, population density, and habitat type. — Recent Publications in Canadian Herpetology — News and Announcements — CHS/SHC Membership Form.

Upcoming Meetings and Workshops

2016 Forests Ontario Conference

The 2016 Forests Ontario Conference to be held 5 February 2016 at Nottawasaga Inn, Alliston, Ontario. The theme of the conference is: 'Regeneration'. Registration is currently open. More information is available at http://www.forestsontario.ca/index.php/annual_conference.

Entomological Society of America – Southwestern Branch Meeting

The 64th annual meeting of the Southwestern Branch of the Entomological Society of America to be held 21–25 February 2016 in Tyler, Texas. More information is available at http://www.entsoc.org/southwestern/2016-southwestern-branch-annual-meeting.

Wisconsin Wetlands Association Annual Meeting

The 21st annual meeting of the Wisconsin Wetlands Association to be held 23–25 February 2016 in Green Bay, Wisconsin. Registration is currently open. More information is available at http://conference.wisconsinwetlands.org/.

2016 Alberta Chapter of The Wildlife Society Annual Conference and Meeting

The 2016 Alberta Chapter of The Wildlife Society Annual Conference and Meeting to be held 4–6 March 2016 at the Badlands Community Facility, Drumheller, Alberta. The theme of the conference is: 'Evolution in a rapidly changing environment. Can lessons from the past direct future wildlife conservation?' More information is available at http://www.actws.ca/conference/.

Wildland–Urban Interface 2016

Wildland–Urban Interface 2016 to be held 8–10 March 2016 at the Peppermill Resort, Reno, Nevada. Registration is currently open. More information is available at http://www.iafc.org/micrositeWUI/homeWUI.cfm?ItemNumber=7987.

Entomological Society of America – Southeastern Branch Meeting

The 90th annual meeting of the Southeastern Branch of the Entomological Society of America to be held 13–16 March 2016 in Raleigh, North Carolina. Registration is currently open. More information is available at http://www.entsoc.org/southeastern/2016-southeastern-branch-annual-meeting.

American Fisheries Society – Washington-British Columbia Chapter Annual General Meeting

The 2016 annual general meeting of the Washington-British Columbia Chapter of the American Fisheries Society to be held 28–31 March 2016 at Campbell's Resort, Lake Chelan, Washington. The theme of the conference is: 'Building a Future for our Fishes'. More information is available at http://agm.wabc-afs.org/.

US Regional Association of the International Association for Landscape Ecology Annual Meeting

The 2016 annual meeting of the US Regional Association of the International Association for Landscape Ecology to be held 3–7 April 2016 at the Asheville Renaissance Hotel, Asheville, North Carolina. The theme of the conference is: 'Landscape Change'. Registration is currently open. More information is available at http://usiale.org/asheville2016/.

Entomological Society of America – Pacific Branch Meeting

The 100th annual meeting of the Pacific Branch of the Entomological Society of America to be held 3–6 April 2016 at the Pacific Beach Hotel, Honolulu, Hawaii. The theme of the conference is: 'Science for the Next Century'. More information is available at http://www.entsoc.org/pacific/2016-pacific-branch-annual-meeting.

Northeast Fish & Wildlife Conference

The 72nd annual Northeast Fish & Wildlife Conference to be held 3–5 April 2016 at the Westin Annapolis, Annapolis, Maryland. More information is available at http://www.neafwa.org/.

Eastern Bird Banding Association Meeting

The 2016 Eastern Bird Banding Association Meeting to be held 8–10 April 2016 at the Blackwater Falls State Park, West Virginia. The theme of the meeting is: 'Birding with a Purpose: Banding to Further Bird Conservation'. More information is available at http://www.easternbirdbanding.org/2016-ebba-meeting/.

Northeast Natural History Conference

The 16th Northeast Natural History Conference to be held 22–24 April 2016 at the Sheraton Springfield Hotel, Springfield, Massachusetts. Registration is currently open. More information is available at http://www.eaglehill.us/NENHC_2016/NENHC2016.shtml.

The Ottawa Field-Naturalists' Club Awards for 2014, presented April 2015

ELEANOR ZURBRIGG, IRWIN BRODO, JULIA CIPRIANI, CHRISTINE HANRAHAN, ANN MACKENZIE and KAREN MCLACHLAN HAMILTON

On April 18th, 2015 members and friends of the Ottawa Field-Naturalists' Club gathered for the Club's Awards Night at St. Basil's Church in Ottawa to celebrate the presentation of awards for achievements in the previous year. Awards are given to members or non-members who have distinguished themselves by accomplishments in the field of natural history and conservation or by extraordinary activity within the Club. Six Club awards were presented for 2014, for: (1) furthering the knowledge of butterflies, (2) promoting the Club and engaging members, (3) long time service as Copy Editor for one of the Club's publications, (4) rescuing birds, (5) protecting ecologically valuable land, and (6) raising ecological awareness in the Ottawa area.

As well, the President's Prize was presented to two recipients in recognition of unusual support of the Club through development of a commemorative fern garden and raising the Club's profile through a birding conference.

Honorary Member: Ross Layberry

This award is presented in recognition of outstanding contributions by a member or non-member to Canadian natural history or to the successful operation of the Club. Usually people awarded an honorary membership have made extensive contributions over many years.

Ross Layberry's name is synonymous with the study of butterflies in the Ottawa region. However, his contributions extend far beyond our local boundaries, and he is recognized and respected by lepidopterists across the country for his expertise and wide knowledge of Canadian butterflies.

When he was awarded the Anne Hanes Natural History Award in 2008, it was noted that Ross is "*a keen field observer, meticulous collector of data, discriminating collector of specimens, and even a careful rearer of immatures. This has enabled him to fill in many gaps in our knowledge of the butterflies and, more importantly, to make that information available to all through his lucid writing.*"

Ross's contributions to our knowledge and understanding of butterflies are manifold. He is certainly well-known as one of the authors of the seminal work on Canadian butterflies, *The Butterflies of Canada*, published in 1998 by the University of Toronto Press. In 1982, he, along with Peter Hall and Don Lafontaine, published an important article in *Trail & Landscape*, on the status and distribution of butterflies in the Ottawa District, the first such compilation for our area. Years later, in 2007, Ross prepared a significantly updated summary, delineating changes in status and additions to the butterfly fauna of the Ottawa region.

Ross's enthusiasm and his desire to help others learn more about butterflies is greatly appreciated, as is his ready willingness to answer any and all questions concerning butterflies. He is an indefatigable contributor to the local online butterfly group, where he shares photos and observations, discusses the results of his larvae rearing, and posts butterfly-related articles both scholarly and popular. He poses interesting questions to the group and engages in discussions about the many aspects of butterfly ecology.

Under the auspices of Agriculture and Agri-Food Canada in Ottawa, he helped to create and maintain the Canadian Biodiversity Information Facility database which contains thousands of butterfly records. In fact, Ross is considered to be a database pioneer in the field of Lepidoptera.

He was the Ontario and Quebec compiler for the Lepidopterists' Society's annual report. In more recent years he compiles and coordinates Ontario and Quebec records submitted to *eButterfly*, and vets them for accuracy.

Ross also works closely with the Toronto Entomologists' Association on their *Ontario Butterfly Atlas Online*, and is one of the three editors responsible for this vast collection of records. Furthermore, Ross is lead editor and compiler for the Association's *Ontario Lepidoptera*, an annual summary of Ontario records. A prolific writer, many of Ross's articles can be found in this annual publication. He is particularly interested in the rearing of larvae and has written on the rearing of Giant Swallowtails, Mourning Cloaks, and Pearl Crescents, amongst other topics.

In recognition of his long-standing work on Canadian Lepidoptera Ross, in 2001, was given the Norman Criddle Award by the Entomological Society of Canada. This award "*recognizes the contribution of an outstanding non-professional entomologist to the furtherance of entomology in Canada*".

The OFNC is proud and privileged to recognize Ross Layberry for his significant contribution over many decades to furthering our knowledge of Canadian butterflies, by naming him an Honorary Member.

(Prepared by Christine Hanrahan)

Member of the Year: Natalie Sopinka

The OFNC's Member of the Year award recognizes a member judged to have contributed the most to the Club in the previous year.

We are recognizing Natalie Sopinka because she exemplifies the impulse to share one's appreciation and knowledge of nature with others. When she joined the Club, Natalie was a PhD candidate from the University of British Columbia, completing her research in a University of Ottawa laboratory.

Natalie asked to join the Education and Publicity Committee upon her arrival in Ottawa in Fall 2013, before she had attended an OFNC event. As a member of the committee, she was reliable, generous, cheerful, and optimistic. Her contributions to the Club and the committee have been considerable. They include supporting the Education and Publicity Committee, promoting a wide range of Club activities, capturing highlights of Club events and publishing her descriptions on the website.

When the committee decided to update the Club's display posters, Natalie taught herself the MS Publisher layout software and created files for attractive posters describing how to join OFNC, OFNC publications, the Macoun Club, and the Fletcher Wildlife Garden. During her presentation to members of the Macoun Club they learned about threats to Pacific salmon and how the salmon are being studied. She re-activated the OFNC's Twitter account, tweeted frequently about OFNC activities, and attracted 329 followers. She staffed OFNC displays at Nature Canada's Bird Day, Agriculture Canada's Bug Day, and the Ontario Field Ornithologists conference, generating interest in the Club by engaging participants with energy and humour. On Bird Day she collected "nesting" materials and joined kids in building human-scale birds' nests on the grounds at Andrew Haydon Park. To further support youth she assisted in selecting two young naturalists for OFNC's sponsorship to the fifth Ontario Nature Youth Summit and judged projects at the Ottawa Regional Science Fair for the OFNC's special awards.

Natalie is particularly skillful at popularizing scientific work. She created the OFNC blog, "Field Notes", in November 2013. Over the time she was in Ottawa, about half of the stories on the blog were written by her and she contributed to all the rest. In total we can thank her for over 50 posts summarizing monthly meetings and events, writing profiles of OFNC members, and accounts of others' work on ecological concerns of the region. Twenty other members were also encouraged by her to contribute to the blog. She managed the blog website and coordinated the work of its small editorial team. Before her departure, she supervised an Ottawa University student volunteer who was reporting on OFNC's Fall 2014 events.

It is for her many contributions to engage others and for promoting the Club that we want to recognize Natalie as Member of the Year.

(Prepared by Julia Cipriani, based on notes from Lynn Ovenden)

George McGee Service Award: Elizabeth Morton

The George McGee Service Award is given in recognition of a member who has contributed significantly to the smooth running of the Club over several years.

Elizabeth Morton joined the OFNC in 1985 and almost immediately began helping with *The Canadian Field-Naturalist* (*CFN*) by responding to a request for volunteers. At that time her English literature training made her ideal as Editorial Assistant. She continued in that position until 1989. It was also around that same time when she joined the Publications Committee.

Liz served as Editor of *Trail & Landscape* for the 1990 volume, covering many general Club and birding activities, as well as environmental concerns such as the Albion Road Wetlands and the Spring Hill bog.

In 2002, Liz officially became Copy Editor of *CFN*. In this role, she was responsible for the proof-reading and editing of manuscripts on a huge variety of subject matter from authors of diverse backgrounds. With her keen eye, attention to detail, and knowledge of natural history, she performed her job with extraordinary skill and patience and provided reliable help to the Associate Editors and the Editor-in-Chief. The majority of her editorial comments were incorporated into the manuscripts.

Liz is a well-organized collaborator, an important quality in helping to keep the Editor on schedule. She remained as Copy Editor until *CFN*'s transition from print-only to print-and-electronic versions making her "the constant" during the editorial and committee change-over. She retired only when the transition was complete. During her tenure as Copy Editor, she reviewed, on average, 74 articles (representing about 575 pages) annually. All this was done while maintaining her day job.

Liz served on the Publications Committee for 28 years, offering advice and giving insights into the production of *CFN*. More recently, she participated in the Publications Committee's *ad hoc* sub-committee investigating the feasibility of *CFN* becoming electronic. This three member sub-committee looked at various publication systems available, assessed the suitability of each with respect to *CFN*, and submitted recommendations to the Publications Committee and Council.

The OFNC is pleased to present Elizabeth Morton the George McGee Service Award for her many years of dedicated work on *The Canadian Field-Naturalist* and within the Publications Committee.

(Prepared by Karen McLachlan Hamilton, with information from Francis Cook and Sandra Garland)

Conservation Award – Member: Anouk Hoedeman

The Conservation Award – Member is given in recognition of an outstanding contribution by a member to the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

For 2014 we are recognizing the work of Anouk Hoedeman for establishing the FLAP program in Ottawa as well as her ongoing work on the Birds Committee and her contribution to the Falcon Watch Program.

FLAP stands for the Fatal Light Awareness Program. This program was founded in 1993 in Toronto to address the issue of bird collisions with human-built structures. Across North America it is estimated that the number of birds killed annually in collisions with buildings ranges from 100 million to one billion.

Thanks to the extensive work of Anouk over the past few years we now have a chapter of FLAP in Ottawa. For her it began with reports of a number of Cedar Waxwings (*Bombycilla cedrorum*) dying when they hit the glass connecting the old and new City Hall buildings. Anouk started asking what was being done and found out that no one was doing anything. She took it upon herself to rectify that situation.

Anouk contacted FLAP in Toronto and went through the necessary training to establish a chapter in Ottawa. There are a lot of details and bureaucracy starting up any program. Of particular importance were the working relationships she established with the Wild Bird Care Centre, Nature Canada, and downtown property managers. When you start patrolling around big downtown office towers early every morning you want to make sure the security officers and maintenance workers do not see you as a threat. It is even better if they are helping you in your quest to retrieve the dead birds and hopefully find some live injured ones. The fact that Anouk patrols by bike might make her seem less threatening or maybe just a bit more peculiar.

Along with her group of volunteers she saves the lives of some stunned birds by either sheltering them until they have recovered from their window strike or taking them to the Wild Bird Care Centre for convalescence. Her inventory of species and number of birds both killed and saved provides an interesting record of bird movements through the city with some surprising findings such as a Boreal Chickadee (*Poecile hudsonicus*) and a Black-backed Woodpecker (*Picoides arcticus*).

Raising awareness of the issue is extremely important if there is to be any reduction in the fatality of birds from window strikes. Anouk has used the media to get the message out with newspaper articles and interviews. The OFNC website, social media, and public speaking are all part of her arsenal of outreach tools. Her enthusiasm is a natural draw to get others engaged.

Anouk's contribution to bird conservation in Ottawa did not start with FLAP. The Falcon Watch program has also benefited from her abilities to arrange logistics with building managers and to recruit volunteers to keep watch on the fledglings that may need rescuing. In recent years the falcons downtown were not successful at producing chicks. However, in 2013 the Heron Road site was spotted and that has been successful for the last couple of years. Anouk coordinates it all while keeping the website up to date with chatty daily postings and pictures.

We are pleased to recognize the work of Anouk Hoedeman with this Conservation Award.

(Prepared by Ann MacKenzie)

Conservation Award – Non-Member: Paul and Cathy Keddy

This award is given in recognition of an outstanding contribution by a non-member to the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

This year the award goes to long-time Ottawa Valley naturalists Paul and Cathy Keddy in recognition of their outstanding contribution to land conservation in Lanark County. In 2014, they donated a portion of their 250-hectare property to a local land trust and entered into a formal 999-year agreement to protect the remainder in perpetuity. Called the Keddy Nature Sanctuary, it is a magnificent forest and wetland landscape on the Canadian Shield, located approximately 45 kilometres west of Ottawa.

Over the past four decades, Paul and Cathy have put their money where their hearts and minds were, incrementally buying tracts of this richly diverse land to protect it in a natural state for all the wild species that live there. They purchased their first parcel of forest in the 1970s while they were students at Dalhousie University, then added to it as properties became available, amassing a tract of ecologically valuable land. There is a wide variety of representative and rare features including both regionally and nationally rare species. Nearly 60 hectares of the property has been designated as a Provincially Significant Wetland Complex.

The Keddys were determined that their "square mile of forest and swamp" remain in a natural state in perpetuity, that future owners not be able to log the 120-year-old oaks or develop the land. They partnered with the Mississippi Madawaska Land Trust, donating a portion of their property, and protecting the rest through a long-term conservation easement that restricts any future development. While the Keddys will continue to live on their property, when it eventually passes to future owners the easement will continue to protect the property and the Land Trust will monitor this. In this way, Paul and Cathy have ensured the permanent protection of that landscape and the ecological functions which sustain it.

This is only the most recent in a long list of ecologically-based undertakings in and about the Ottawa Valley initiated by the Keddys. During lengthy careers as prominent professional biologists, they have conducted numerous investigations that have clarified, explored and documented important natural landscapes and features. These have led to significant conservation achievements both locally and beyond.

This latest positive conservation action by Paul and Cathy Keddy is an inspiration to other field naturalists and conservationists.

The OFNC is honored to present Paul and Cathy Keddy with its Conservation Award for a non-member.

(Prepared by Eleanor Zurbrigg, based on material from Dan Brunton and the website of the Mississippi Madawaska Land Trust, accessed February 2015, http://mmlt.ca/protecting-nature/our-protected-properties/keddy-nature-sanctuary/)

Mary Stuart Education Award: Tom Spears

The Mary Stuart Education Award is given in recognition of outstanding achievements in the field of natural history education in the Ottawa Region. In most years, the awards are made to schoolroom teachers or those associated with the local Boards of Education, but this year, we have cast our net more broadly.

Newspaper reports on scientific discoveries and environmental issues are notorious for errors, half-truths, and exaggerations. Too often, scientists and environmentalists avoid interviews with the local media due to the fear of being misquoted or misunderstood. Not so in Ottawa, where the *Ottawa Citizen* has Tom Spears looking after these topics. His clear and illustrative reporting of often complex and seemingly academic issues that are nonetheless important for both the invested and general public to understand, has been remarkable. Tom has dealt with topics ranging from exposing the antics of pirate scientific journals, reporting important conservation achievements, tracing the redevelopment of forests after fires, wolf studies in Gatineau Park, and the discovery of rare and ecologically critical species, to unravelling unwieldy and environmentally counter-productive bureaucratic processes.

Often as not, his writing captures quirky aspects of the subject, never getting more serious than necessary but always mindful and respectful of the important core message. Tom Spears employs only solid, verifiable, and science-based documentation before he speaks. He checks first with scientists and researchers with proven credibility concerning the issue and frequently consults scientific primary sources including our own *Canadian Field-Naturalist* for references. Tom puts the needs, nature, and remarkable characteristics of the natural world front and centre in a credible, verifiable, and accessible manner that both informs and inspires his readers. In doing this Tom has contributed to a greater level of ecological awareness in and of the Ottawa Valley and beyond (his articles frequently being picked up nationally or internationally). Perhaps his greatest contribution is promoting a greater public understanding of the need for informed, fact-based decision-making in natural environment management.

Tom Spears is from the Toronto area and developed his love of the outdoors during cottage summers by Lake Huron with his parents. He and his wife now own 13 acres of forested land in the Gatineau Hills. Although Tom doesn't regard himself as a naturalist and lacks formal education in science (having majored in French and history at York University), he has a strong love of the outdoor experience and can recognize many of the birds and flowers he encounters.

Tom came to the *Ottawa Citizen* 25 years ago, after having been a reporter for the *Peterborough Examiner*, *Ottawa Journal*, *Montreal Gazette*, and *Toronto Star*. He was on night shifts at the *Toronto Star* when the environmental reporting job opened up, which would mean day shifts Monday to Friday, so he jumped at the chance. Although Tom is a "general assignment reporter", the *Ottawa Citizen* normally directs the science stories to him, for which he is very grateful, and we should be too. Tom has done an exceptional job of teaching science to the layperson, and for this, we award him this year's Mary Stuart Education Award.

(Prepared by Irwin Brodo and Dan Brunton)

President's Prize: Elisabeth Allison

This award is given at the President's discretion for singular contributions to our Club that do not quite fit the other Club awards categories.

Four years ago, the Fletcher Wildlife Garden needed someone with knowledge of ferns and their discrete habitats to create a fern trail in memory of Bill Cody, a fern specialist and a long-time member of our Club. Lis Allison took on this project in the Ash Woods. Now, as most of you know, those woods have been destroyed by the Emerald Ash Borer (*Agrilus planipennis*). The ash trees had to be cut down and in the process the fern garden, which had become nicely established under these trees, was also destroyed.

A decision was made to recreate a fern garden at the rear of the Backyard Garden. Lis gallantly took on the task to redesign that area to make it a suitable space for ferns. There was plenty of shade for shade-loving ferns but other habitats needed to be created. Using a pond liner and doing some heavy digging, she fashioned a small wetland for the water-loving ferns and built a lovely stone wall for the rock-dwelling ferns. Voilà, we now have a Fern Garden with about 39 of the 43 ferns that grow in the Ottawa area. Many of these ferns came from Lis's own garden.

It is my pleasure to present the President's Prize to Elisabeth Allison with thanks from our Club.

(Prepared by Fenja Brodo, President, based on material from Isabelle Nicol)

President's Prize: Robert Cermack

This award is given at the President's discretion for singular contributions to our Club that do not quite fit the other Club awards categories.

The OFNC has always been strong in birding. This is probably the most popular activity among our club members. So when Bob Cermak came to the Board requesting support for hosting the annual OFO (Ontario Federation of Ornithologists) Convention in Ottawa we were pleased to support this.

Bob had a vision and a plan. It involved getting leaders from his many birding friends, including OFNC members, but more importantly, birders from several other sister clubs in the region. It was a cooperative event that offered an amazing total of 29 field trips led by 38 leaders, over the three-day Convention in September 2014. Participants had hard choices to make. At the beautifully organized Convention dinner I heard the enthusiasm and delight expressed by attendees, asserting this to be one of the best OFO Conventions ever. This was a tribute to Bob's organizational skills; he did our Club proud. That is why I am presenting Bob with the President's Prize.

(Prepared by Fenja Brodo, President)

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Compiled by William Halliday

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ISSN 0008-3550